TM 1-219

WAR DEPARTMENT

TECHNICAL MANUAL

BASIC PHOTOGRAPHY

July 1, 1941

TECHNICAL MANUAL
No. 1-219

WAR DEPARTMENT,
WASHINGTON, July 1, 1941.

BASIC PHOTOGRAPHY

Prepared under direction of the
Chief of the Air Corps

*This manual supersedes TM 2170-5, March 1, 1930.

298620°—41——1

CHAPTER 1

GENERAL

1. Definition.—Photography is an accurate means of recording information of terrain, individuals, objects, and events. It is also a means of communication. It is a medium of vital importance to the commander in obtaining information of a strategical, tactical, or technical nature.

2. Purpose and scope.—This manual serves as a reference to basic photographic principles and to the technique of military photography. It includes elementary photography, chemistry, sensitized materials, optics, filters, photographic sensitometry, ground camera photography, negative making, printing, copying, lantern slides, color photography, and laboratory operations.

3. References.—*a. Army Regulations.*—Instructions relating to the responsibility for obtaining, handling, storing, and distributing photographs are contained in AR 95–5, 105–255, 105–260, 300–15, 600–700, and 850–65.

b. Field Manuals.—Matters pertaining to photography are contained in FM 1–35, 30–20, and 30–21.

c. Technical Manual.—Operation and methods incident to the making of aerial photographs and aerial photographic products and their application to various purposes are described in TM 1–220.

d. Technical Orders.—Information and instruction relative to specific items of Air Corps photographic equipment are set forth in Air Corps Technical Orders. A complete list of Technical Orders giving detailed directions for the operation and maintenance of all standard items of Air Corps photographic equipment is contained in Air Corps Technical Order 00–1.

e. Air Corps Circulars.—Air Corps Circulars of the 95 series contain additional instructions pertaining to Air Corps photography.

4. Photographic units.—Tables of Organization provide photographic units for many types of Air Corps organizations. Whereas some units are independent organizations and others are sections of Air Corps tactical or base organizations, all require the services of specially trained technicians.

5. **Responsibility for photographs.**—*a. Aerial.*—The Air Corps is charged with the responsibility of performing all photographic and cinematographic work from aircraft. To this type of photography is applied the general term "aerial photography."

b. Ground.—At stations where Air Corps troops predominate, the Air Corps is responsible for performing the essential ground camera photography that is normally done for the War Department by the Signal Corps.

c. Procurement.—Responsibility for procurement of photographs is a function of command.

d. Execution of missions.—Each commander having photographic equipment under his control is responsible for the prompt execution of all photographic missions assigned to his unit.

e. Photo officer.—A specially trained technician known as a photo officer is a member of the special staff of the commander of each unit having photographic responsibilities. The photo officer acts as an adviser to the commander on all technical and tactical applications of photography. He is charged with the technical proficiency of the photographic laboratory and with the technical training of the personnel detailed to photographic duties.

Chapter 2

ELEMENTARY PHOTOGRAPHY

Section I

GENERAL

6. **Use of equipment.**—Photographic equipment will be used only by personnel trained in its operation.

7. **Attainment of quality.**—The finished photograph is the result of many successive operations. The quality of the final product depends upon the satisfactory completion of each of these successive steps. At all times, the progressive photographer must be the severest critic of his own work. Every negative and print made will be studied in order that the experience gained will result in further improvement.

Section II

CAMERA OPERATION AND LABORATORY TECHNIQUE

8. **General.**—The making of any photograph involves camera operation, and laboratory work called "processing."

9. **Principle of the camera.**—The camera is a lighttight chamber having at one end a lens and at the other a place to insert a holder containing a film coated with a light-sensitive emulsion (fig. 1). This emulsion consists of a gelatin base in which are incorporated minute grains of a silver halide. The camera is focused on the object to be photographed; the holder, which has been previously loaded in a darkroom with the light-sensitive material, is inserted and the protective slide withdrawn. The shutter of the camera is then opened, allowing the rays of light reflected from the subject to pass through the lens, which forms the rays into an image of the

subject. This image is projected or impressed upon the film for a period of time called the "exposure time" and the shutter of the camera is then closed. A camera shutter is usually automatic, opening when pressure is applied to the actuating lever and closing automatically at the expiration of the time for which it is set. The exposure time is usually a fraction of a second.

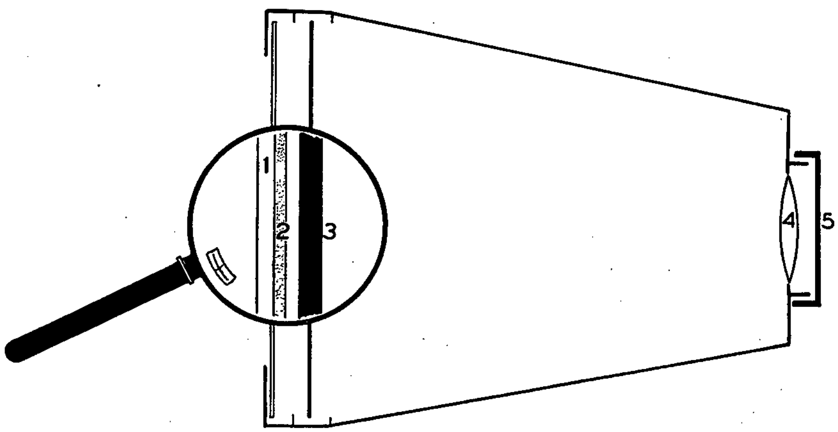
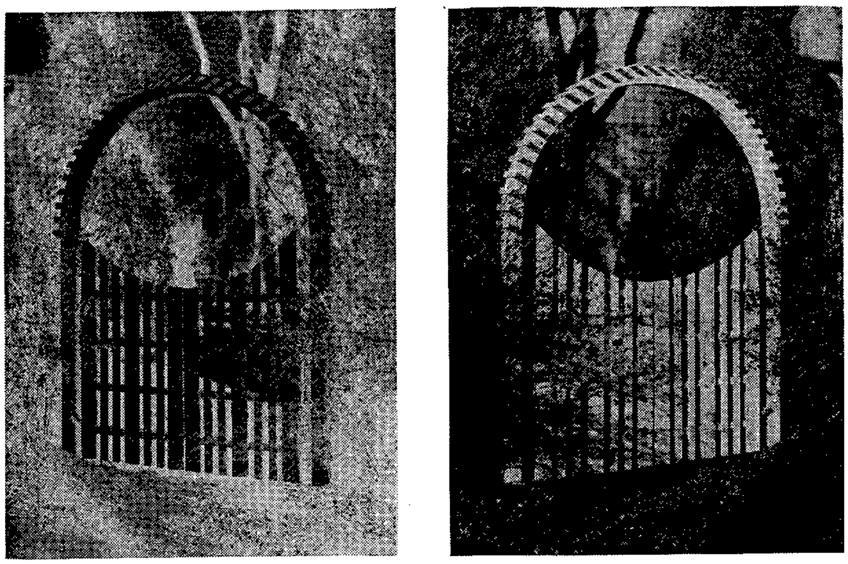


FIGURE 1.—The camera.

10. Laboratory processing.—The image registered by the exposure of the emulsion is invisible, or latent, and must be made visible by development so that it can be seen and used. The film must be developed in a darkened laboratory. During development, the exposed crystals of silver halide composing the latent image are changed into metallic silver grains which form the visible image. This image, however, is negative; that is, it is reversed as to light and dark so that whatever is light in the subject appears dark or dense in the negative. Upon completion of the negative, the next step in the process is the production of the positive image in which the light and dark areas correspond to those of the subject. This positive image is the photograph (fig. 2②). The process of making positive photographs on paper is called printing and is accomplished on a printing machine. A laboratory, which is illuminated with light to which the paper is not sensitive, is used for the purpose. The negative and sensitized paper are placed in correct relation to each other in the machine. When the machine is operated, white light is transmitted through the negative, registering a latent image within the emulsion of the paper. The exposed sheet of paper is then developed by a process similar to that used to develop the negative.



① Negative. ② Positive.

FIGURE 2.—Negative and positive images.

SECTION III

ESSENTIALS IN MAKING A PHOTOGRAPH

11. General.—In order to produce a photograph on paper there must be light, subject, lens and shutter, camera, photographic emulsions, and photographic chemicals.

12. Light.—Light is a form of radiant energy and travels in straight lines. This is seldom noticeable in daylight, but if light enters a darkened room through a small opening it will travel in a straight beam. This is evidenced by dust particles in the air which reflect light, making it visible. It is this property or reflection of light which makes photography possible since all parts of an object will reflect light in all directions. The number of rays reflected depends upon the reflective power of the object.

13. Subject.—Light illuminating a subject is reflected in varying intensities from different areas of the subject. An area of the subject from which an intense light is reflected is called a "highlight," and one which reflects light of very low intensity is called "shadow." Those areas reflecting intermediate intensities are known as "halftones." Light which is not absorbed is reflected, the reflection varying in intensity according to its original intensity and amount of absorption within the subject. It is the function of photography to record these many and varied light intensities of the subject. The photographic recordings also vary according to the colors of the objects composing the subject and the sensitivity of the film to those particular colors. From almost every point of the subject, innumerable rays of light are reflected. These innumerable rays of light in passing through the camera lens are refracted in such a manner that an image of the subject is formed and projected upon the film.

14. Lens and shutter.—*a.* A photographic lens is a circular glass or combination of glasses which is so ground that it will project an image. The lens is used in the front part of the camera.

b. A shutter is a mechanical device that regulates the length of time that light passes through the lens. An iris diaphragm is generally incorporated in the shutter to regulate the amount of light passing through the lens.

15. Camera.—Essentially, a camera is a lighttight chamber. Its purpose is to exclude all light that does not pass through the lens.

16. Emulsion.—*a.* The function of photographic emulsion is to retain the image registered by the action of light. A light-sensitive emulsion is composed of gelatin coating throughout which are distributed minute crystals of a silver halide.

b. It is not definitely known exactly what change takes place in a photographic emulsion when it is exposed to light. However, it is known that the exposed silver halide crystals are altered in some manner which makes them developable.

(1) The generally accepted theory to explain the effect of light on a silver halide crystal is that during the process of ripening one or more silver sulfide specks are formed on each silver halide crystal. These specks are formed by silver combining with the sulfur which is present in certain organic compounds which are found in some types of gelatin. It is thought that this sulfide speck causes strains in the structure of the silver halide crystal. These strains are such that when light strikes the crystal the speck will concentrate the effects of the light so that a developable nucleus is formed.

(2) The number of silver halide grains affected by an exposure depends upon the sensitivity of the grains, the intensity of the light striking the emulsion, and the length of time the light is allowed to strike the emulsion.

c. Theory of development.—It has been explained that the effects of light on a silver halide crystal are concentrated in one portion of the crystal to form a developable nucleus. During development the silver is separated from the exposed crystal. This silver is metallic and is in the form of extremely minute particles. When the developing solution surrounding the crystal becomes saturated, the silver begins to deposit on the nucleus of the grain. As development continues, more silver is released from the crystal. This silver first goes into solution and then deposits on the nucleus. This continues until finally a grain of silver of minute size is formed. During development this same change occurs in all the other exposed silver halide crystals which form the latent image. Thus the latent image is changed to a metallic silver image. Since there is no developable nucleus in the unexposed silver halide crystals, the unexposed crystals are not affected by the developer.

Section IV

PROCESSING

17. Development of emulsion.—The purpose of development is to make the latent image visible. An exposed emulsion bearing a latent image has the same appearance before development as one which has not been exposed. This development is accomplished in a darkroom. As has been explained, the developer will change the silver halide grains which have been rendered developable by the action of the light into grains of metallic silver (fig. 3). When all the developable grains have been changed to metallic silver, development is complete. The time necessary to develop an emulsion varies widely with different types of emulsions and different developing solutions. The time of development is usually not less than 1 minute or more than 30 minutes. At the completion of development, the negative is rinsed and then placed in a fixing bath.

18. Fixation.—*a.* Fixation dissolves unexposed silver halide, thereby permitting its removal by washing in water. If an emulsion

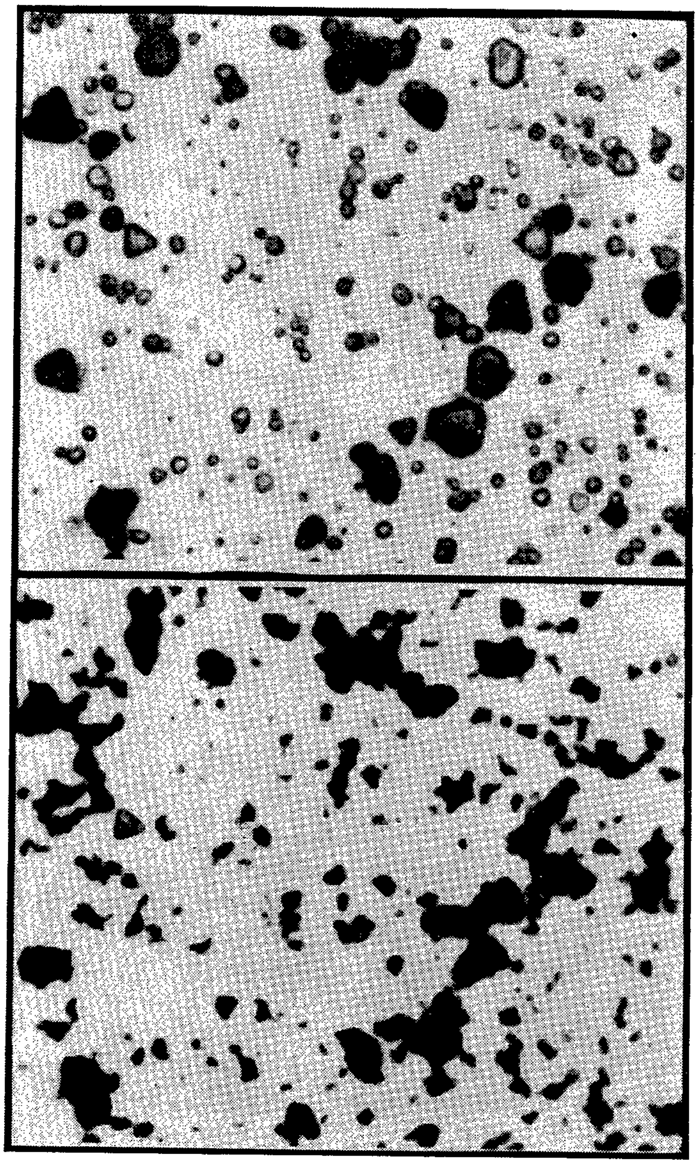


FIGURE 3.—Developed and undeveloped grains. (2500×)

is not fully fixed, some silver halide will not be dissolved and therefore cannot be removed in washing. Silver halide remaining in an emulsion will be affected by light and upon prolonged exposure will become discolored. This discoloration or darkening may be so great as to obliterate completely the image.

b. The principal ingredient of the fixing bath is sodium thiosulfate, commonly called "hypo." This chemical changes the halide into silver sodium thiosulfate which is soluble and is removed from the film in the plain water washing that follows the fixing bath. Ordinarily, complete fixation is concluded when the film has remained in the fixing bath twice the length of time that it has taken for the milky appearing silver halide, unaffected during exposure, to disappear and the negative to become transparent. The metallic silver image ordinarily is not affected by the fixing solution. However, if fixation is prolonged or the solution is at a temperature higher than that at which it should be used, the metallic image will begin to bleach.

19. Washing.—When the film has been completely fixed, the negative is thoroughly washed in water for not less than 20 minutes to remove the thiosulfate of silver and all chemicals of the fixing bath from the emulsion. The negative is then dried and is ready for use.

20. Identification of photographs.—The identification of a photograph is a responsibility of the cameraman. At the time of processing he must furnish the laboratory technician with the title and data that must be affixed to the negative or print. All photographic personnel must realize that a poorly or an improperly identified photograph is generally valueless and may, in the case of improper identification, be harmful in the proper execution of the mission.

Chapter 3

CHEMISTRY

Section I

GENERAL

21. General.—The greater portion of a photographer's work consists of processing sensitized emulsions. This involves the use of chemical solutions. In order that these solutions may be used intelligently, a few principles of chemistry are reviewed and the nature of photographic emulsions described. The functions and application of developing solutions and fixing baths, and information regarding the proper temperatures of solutions, the washing of negatives and prints, and the reduction and intensification of negatives are discussed.

22. Importance of uniform solutions.—Military photographs of high quality can best be secured when all the solutions used in processing are mixed properly and of uniform strength. When the factors or processing remain constant, the photographer is enabled to control the variables of exposure to a much greater degree. It is therefore essential that each laboratory technician mix solutions exactly as stated in the formulas, and employ them in the manner and at the temperature specified. The advantages of uniform developing solutions are as follows:

a. Facilitate judging of negatives as to exposure and contrast and also for the selection of printing papers.

b. Aid the printer in judging prints for exposure, contrast, density, and color or tone. The judging of color is especially important as the printer can depend on the color being correct only when the developing solution used is of uniform quality.

c. Insure that images will be permanent, not bleached, that the hardening action will be adequate, and that there will be an absence of stains and spots caused by the continuation of development after immersion in the fixing bath.

d. Lend confidence to and assist the photographer in the processes of toning, reduction, and intensification.

Section II

ELEMENTARY

23. Classification.—Chemicals in general are classed as elements or compounds.

a. Elements.—An element may be defined as the simplest form of matter. Carbon is the most common element and is familiar to everyone. Other well-known elements are oxygen, iron, silver, gold, sulfur, hydrogen, mercury, bromine, chlorine, iodine, potassium, and sodium.

b. Compounds.—There are approximately 90 elements and they combine in definite proportions to form great numbers of substances of fixed composition which are termed "compounds." When matter is not found in definite proportions, the combination is termed a "mixture." A compound may contain only two or it may contain several elements. If two parts of hydrogen are combined with one part of oxygen, the resultant compound is water designated by the chemical symbol H_2O. An example of a compound containing more than two elements is sodium carbonate, which is used frequently as an accelerator in photographic developers. From its chemical symbol Na_2CO_3, it is seen that sodium carbonate is a compound containing two molecules of sodium, one molecule of carbon, and three of oxygen.

24. Altering compounds.—The nature of compounds may be changed by means of certain agents, such as light, heat, or electricity, and by the addition of other elements or other compounds. That is, one or more of the elements which form the compound may be released. The released elements may be collected separately or they may combine and form entirely different compounds. The solutions used in photographic work are merely correct combinations of the proper chemicals which will cause desired chemical changes in photographic emulsions. For this reason, before taking up photographic formulas and the functions of the different chemicals, photographic emulsions must be considered.

Section III

EMULSIONS

25. Gelatin.—*a.* Gelatin is used to hold the silver halide of photographic emulsions in suspension. While collodion and albumin were formerly used in emulsions to support the silver halide, gelatin proved so far superior to these substances that it has been almost universally adopted and practically all photographic emulsions now contain gelatin.

b. Gelatin is a byproduct of packing plants, being obtained principally from the hides, bones, and hoofs of animals. Commercially it comes in the form of a powder, flakes, or in shreds. It is a peculiar substance, dissolving readily in warm or hot water but refusing to dissolve in cold water. If placed in cold water, it forms a jellylike mass, the water apparently being absorbed by or dissolving into the gelatin. If dissolved in warm water, it forms a thin liquid. When this solution cools, it will form into jelly even if the percentage of gelatin which it contains is as little as 1 percent. If the jellied gelatin is heated it will liquefy; if cooled, it will set again. This process may be repeated many times, although with continued repetition the gelatin will lose some of its setting qualities.

c. To make a piece of photographic paper, a film, or plate, liquefied gelatin containing silver halide crystals is spread on a proper base. This coating is, at first, quite thick but will soon dry down to a rather thin hard layer. Evenly dispersed throughout the layer of emulsion are innumerable silver halide crystals. The hardness of the gelatin in different emulsions varies. This is because some gelatin is naturally harder than others and because the hardness of gelatin is sometimes increased by the addition of chrome alum.

26. Types of silver salts used.—The photo-sensitive compounds found in all emulsions are called silver halides, which are compounds of silver with bromine, chlorine, or iodine. These silver halides are formed by combining silver nitrate with potassium bromide, sodium chloride, and potassium iodide, respectively. Silver iodide is the least susceptible to the action of light and silver bromide is the most susceptible. However, when silver iodide and silver bromide are combined, they form a much faster emulsion (more susceptible to the action of light) than when silver bromide alone is used. Emulsions are often referred to according to the type of silver compound they contain, such as chloride, bromide, chloro-bromide, or bromo-chloride emulsions.

a. Chloride.—Chloride emulsions are found only on contact printing papers. They usually contain a small amount of silver bromide and often contain a trace of silver iodide. Silver chloride is more readily reduced than silver bromide, which accounts for the fact that the developing time for bromide paper is usually about twice that for chloride paper.

b. Bromide.—All plates, film, fast projection papers, and most lantern slides are coated with emulsions containing silver bromide. These emulsions usually contain some silver iodide. Bromide emulsions are much more sensitive to light than chloride emulsions, sometimes being as much as 1,000 times faster.

c. Chloro-bromide or bromo-chloride.—These two terms are synonymous. This emulsion is used on slow lantern slide plates and on bromo-chloride printing paper. This paper can be used (with a weak printing light) for contact printing but is fast enough for projection printing. There is a great variation in speed of the different brands, but a bromo-chloride emulsion may be considered several times faster than a chloride emulsion and several times slower than the average bromide emulsion. The developing time is longer than that for chloride papers and less than that of bromide paper.

d. Silver iodide.—There is no emulsion in which silver iodide predominates although there is usually some of this chemical present in all bromide emulsions and a small amount in chloride emulsions. Some of the effects of adding silver iodide to emulsions are: first, it is possible to make a faster emulsion by combining silver iodide with silver bromide; second, it increases the contrast; and third, it decreases the tendency of emulsions to chemical fog. When silver iodide is added to a bromide emulsion the sensitivity of the emulsion to the green region of the spectrum is increased.

27. Making a bromide emulsion.—*a.* To make a bromide emulsion, part of the gelatin to be used is made into a jelly by the addition of cold water. This jelly is liquefied by heating, and potassium bromide, which has previously been dissolved in cold water, is added. A predetermined amount of silver nitrate is then added to the solution in the absence of light.

b. When potassium bromide and silver nitrate are combined in the gelatin, silver bromide and potassium nitrate are formed. Silver bromide is practically insoluble in water while potassium nitrate is soluble.

c. After all the ingredients have been added the emulsion may be allowed to jellify. It is then shredded and washed to eliminate the potassium nitrate. In other processes the emulsion is ripened before it is shredded and washed.

d. There are three methods of ripening (or digesting) emulsions. The simplest is to let the emulsion stand for about 24 hours. A second method is to keep the solution at near boiling temperature for several hours, and a third method is to treat the emulsion with ammonia. When an emulsion is ripened before it is washed the ripening process is inclined to increase the size of the silver halide crystals as well as the tendency of the emulsions to produce chemical fog. However, since the speed of emulsions can be increased greatly by ripening, it is considered that the value of increase in speed of the emulsion outweighs the detrimental effects of the increase in size of the silver halide crystals and the tendency of the emulsion to produce chemical fog.

e. After the emulsion has been ripened, the part of the gelatin that has been withheld is added to the solution. At this point potassium chrome alum may also be added to regulate the hardness of the gelatin. If it is to be used for orthochromatic or panchromatic films, the sensitizing dye is incorporated in the emulsion at this stage. The emulsion is now ready to coat on paper, cellulosic film base, or glass, depending upon whether printing paper, film, or plate is being made.

f. When first coated, the emulsion is quite thick but when dry, it contracts to a hard, smooth layer, thinner than an ordinary piece of paper.

28. Silver grains.—*a*. To appreciate the true effect of light and photographic chemicals on photographic emulsions, the individual silver halide crystals must be considered. Although a photographic emulsion is very thin, these crystals are so minute that they lie scattered and apart throughout the emulsion. As a rule in slow emulsions, the crystals are smaller than those in fast emulsions because the faster emulsions are more completely ripened than the slower ones; the ripening process tending to increase the size of the silver halide crystals. In the same emulsion, there is a wide variation in the size of the crystals (fig. 4). In every emulsion, there are many grains of ultra microscopic size but in an ordinary film emulsion, those that can be seen through a microscope will average from $\frac{1}{10000}$ to $\frac{1}{15000}$ of an inch in diameter. It has been estimated that in a 1-inch square section of an average film emulsion there may be 40 billion silver halide crystals. With such an enormous number, in spite of their minute diameter, they must lie many layers deep in the emulsion.

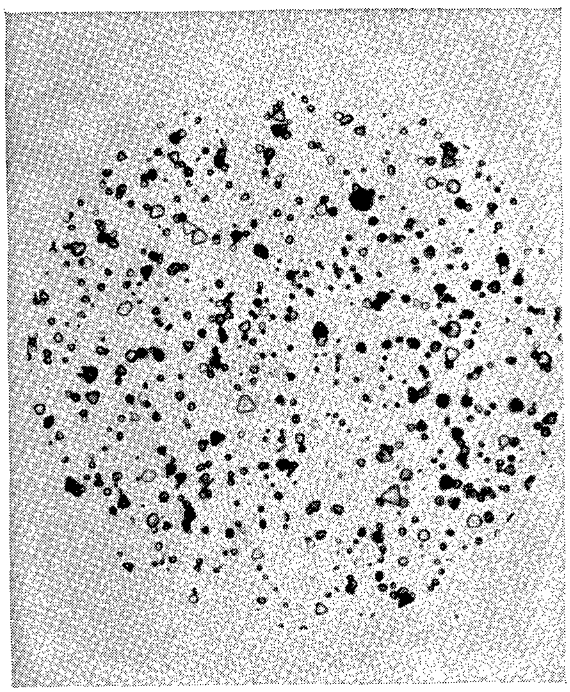


FIGURE 4.—Photomicrograph—silver bromide crystals.

b. There is not only a wide variation of the size of the silver halide crystals in an emulsion but they also vary as to shape and opacity. Their shapes are round, oval, triangular, rodlike, and irregular. Most of them are semitransparent but some scattered few are almost opaque. Although neither the shape nor the transparency seems to have any effect on their senstitivity, there are numerous crystals which for some unexplainable reason are much more sensitive to light than are the majority.

c. The usual conception of the exposure of emulsions is that strong light penetrates deep into the emulsion affecting many layers of crystals, while the less intense light affects only the crystals which lie in the outer layers of the emulsion. This is relatively true, but these supersensitive silver halide crystals are affected by light of low intensity even though they may lie in the lower layers of the emulsion. Therefore, in examining the shadow detail of a negative or the detail in the highlights of a print, it should be realized that at least part of this detail is formed from silver grains which lie deep in the emulsion. One interesting feature of silver halide crystals is, that if a single crystal is affected by light sufficiently to become developable it will be developed completely into metallic silver.

SECTION IV

DEVELOPERS AND THEORY OF DEVELOPMENT

29. Ingredients of developing solutions.—*a.* The ingredients which compose a developing solution may be classified according to their individual functions as follows:

(1) Developing agent or agents.
(2) Keeper.
(3) Preservative.
(4) Accelerator.
(5) Restrainer.

b. The most important chemical in any developing solution is the developing agent or as it is often called, the reducer or reducing agent which actually changes the exposed silver halide crystals to metallic silver grains. Practically all developers are either neutral or only slightly acid. If one of these developers were dissolved in water and an attempt made to develop an exposed emulsion in this solution, there would be little or no reduction of the silver halide crystals because the reducer is not active while in an acid or a neutral state. Therefore, with the exception of one developing agent known as diaminophenol hydrochloride, it is customary to add an alkali to all developing solutions. A developing solution containing only a reducing agent and an alkali would not only develop too rapidly but would be inclined to reduce some of the unexposed silver as well as the exposed. This would cause chemical fog throughout the emulsion and completely spoil the image.

c. To keep the developer from reducing the unexposed silver and to prevent the chemical action from proceeding too rapidly, a restraining chemical, usually potassium bromide, is added to the solution. The solution would now develop an emulsion in a fairly satisfactory manner but would still oxidize too rapidly, probably cause stains, and would rapidly lose its strength. To overcome these difficulties, another chemical which has an affinity for oxygen is placed in the solution. Sodium sulfite in a developing solution will retard the oxidation of the developing agent. It combines with an oxidized developing agent to form mono-sulfonates and di-sulfonates. These chemical compounds formed are usually colorless. Since they are colorless it should be realized that while an exhausted developing solution is usually yellow or brown it is possible to have a badly exhausted solution which is quite clear. If the above chemicals were added in proper amounts to a quantity of water, they would form a satisfactory developer, providing it were used immediately. The chemical used for this is almost invariably sodium sulfite. However, it is far more practical and convenient to mix developers in advance so that they can be used whenever desired. Some developing agents in solution will not keep unless they are in an acid state. To keep the developer in condition until it is used, a small amount of acid or chemical containing an acid is often included as one of the ingredients of the developing solution.

30. Developing agents or reducers.—While there are many chemicals that are capable of reducing exposed silver salts to metallic silver, most of them cannot be used because they are inclined to reduce the unexposed as well as the exposed silver salt. There are only a few developing agents in common use although there are many sold under various trade names which are the same or only slight modifications of these standard few. Although any one of these developing agents will develop an exposed photographic emulsion, they have different characteristics and produce different effects. Monomethyl para-aminophenol sulfate (more commonly called metol), hydroquinone, and pyrogallic acid (trioxybenzene) are the three most used developing agents. With amidol and para-aminophenol, the list of developing agents used in the Air Corps is complete. Some of these agents have a higher developing potential than others. This means that one will reduce silver under adverse conditions where one of a lower potential would not work properly. Such conditions are encountered when using a developing solution that is below normal temperature or when the solution contains an excessive amount of restrainer. Developing agents having a low potential require a stronger alkali and less restraining chemical than those which have a high potential. Of the commonly used developing agents, metol has the highest developing potential.

a. Pyrogallic acid (pyro).—Pyro, which is used only in negative developers, is made from nutgalls which are obtained from the Orient. It is generally used in combination with metol, but may be used alone. When used with decreased amounts of sodium sulfite it produces a deeply stained image. This is considered desirable by many photographers, especially for developing negatives which have been exposed under adverse light conditions. Increasing the amount of sulfite will eliminate practically all this stain. One reason pyro is used so much for developing negatives is that when a small amount of accelerator is used, negatives of low contrast will be secured while negatives of higher contrast will result when the amount of accelerator is increased. Pyro used as a developing agent will tend to prevent the formation of aerial fog. A developing solution containing only pyro as a reducing agent requires little or no potassium bromide. Sodium carbonate is generally used with pyro as an accelerator, although potassium carbonate will work satisfactorily.

b. Monomethyl para-aminophenol sulfate.—This developing agent is derived from coal tar. Its trade names are Metol, Elon, Pictol, and Rhodol. For convenience monomethyl para-aminophenol sulfate is frequently referred to in formulas and photographic literature as metol and that designation will be employed in this manual. When metol is used, the developer must contain a relatively large amount of potassium bromide. Since metol works well with a mild alkali, either sodium carbonate or borax is generally used with it as the accelerator. It is little affected by slight changes in temperature, starts reduction quickly, but produces density slowly. Metol is commonly used in the following types of developing solutions: fine-grain negative developers, with hydroquinone in print developers, in negative developers with pyro, in most motion-picture film developers, and in some lantern slide developers.

c. Hydroquinone or hydrochinon.—This developing agent is derived from benzine. It requires little or no restrainer, is not active at a temperature lower than 55° F, and is inclined to produce fog at temperatures higher than 80° to 85° F. It is nonstaining, develops a pure black image, and is inclined to give contrasty results. It is used in combination with metol in paper developers, in most developers for positive motion-picture film, and in many lantern slide developers especially when contrasty slides are desired. In the last two developers, it is often the only devoloping agent used.

d. Diaminophenol hydrochloride or amidol (*diaminophenol*).—This is a developing agent which is often used in tropical developing solutions but can be used in developers generally. It produces a gray-black image and is especially suitable for use with bromide papers.

(1) Amidol is the only developing agent with which potassium chrome alum can be used in the developing solution because it is the only agent which requires no alkali for acceleration. A solution containing only sodium sulfite and amidol will make a satisfactory developer, but frequently a small amount of potassium bromide is included as a restrainer.

(2) A developer containing amidol oxidizes rapidly and must be mixed immediately before use. It also will deteriorate rapidly in use.

e. Para-aminophenol or para-aminophenol hydrochloride.—This agent is seldom used except in tropical developers. Para-aminophenol hydrochloride (trade name, Kodelon) is somewhat superior to paramidophenol hydrochloride. A developing solution in which para-aminophenol is used as a developing agent requires only a small amount of restrainer. A negative developed in this developer will have a pure black image while the images of prints will be a gray-black color. The rapidity with which a para-aminophenol developer will develop an image decreases rapidly as the solution is being used. This can be prevented by adding, at intervals, small amounts of accelerator to the solution. A developer containing para-aminophenol can be used at high temperatures (90° to 95° F.) without causing chemical fog.

31. Accelerators.—*a.* The accelerator (alkali) in a developing solution energizes the reducing agent and softens the gelatin of the emulsion. The energy with which the developing agent reduces the exposed silver halides to metallic silver depends largely on the amount of alkali present in the solution. The softening of the gelatin allows the developing solution to penetrate and permeate the pores of the gelatin in sufficient quantities so that it can reduce the crystals of exposed silver halide which lie scattered throughout the emulsion.

b. An inadequate amount of alkali in a developing solution will result in insufficient reaction of the developing agent and insufficient softening of the emulsion resulting in a weak image.

c. Too much alkali in a developing solution will cause excessive reaction of the reducing agent which will result in high contrast, an increase in density, stains, chemical fog, and excessive softening of the emulsion.

32. Alkalies used as accelerators.—The list below shows the alkalies used as accelerators and the amount of the different alkalies that would be equivalent in strength to 1 ounce of sodium carbonate (anhydrous). The amount of borax, sodium metaborate, and paraformaldehyde is not given because it is impractical to substitute one of these chemicals for the other alkalies listed. Although the relative strengths of these different alkalies are as accurate as possible, it must be understood that a strong alkali will not give exactly the same results as a weak alkali even if allowance is made for difference in strength. It is customary and practical to substitute one form of sodium carbonate for another, such as crystal for anhydrous, and to substitute sodium carbonate for potassium carbonate, and vice versa.

Sodium carbonate (anhydrous)	1.00
Sodium carbonate (monohydrated)	1.17
Sodium carbonate (crystals)	2.69
Sodium hydroxide	.75
Potassium hydroxide	1.05
Potassium carbonate (anhydrous)	1.30
Potassium carbonate (monohydrated)	1.63
Borax	
Sodium metaborate	
Paraformaldehyde (trioxymethylene)	

a. Sodium carbonate.—This alkali is generally used as an accelerator when pyro is used as a developing agent. It is also used in most metol-hydroquinone developers and sometimes in fine grain and even process developers. As a rule, a milder alkali is used in fine-grain developers and a stronger alkali than sodium carbonate is used in process developers.

b. Sodium hydroxide and potassium hydroxide.—These alkalies are used in process developers when extreme contrast is desired. Sodium hydroxide is used more commonly than potassium hydroxide. Both these chemicals are poisonous and highly caustic. They are usually procured in the form of sticks. When a white encrustation of sodium bicarbonate forms on the sticks it must be scraped away as the encrustation must not be used. When scraping or breaking the sticks, the eyes should be protected by goggles.

c. Potassium carbonate.—Potassium carbonate may be used as an accelerator in any formula which specifies sodium carbonate. It is not so uniform in strength as sodium carbonate and is slightly more expensive. For these reasons, it is seldom used as an accelerator.

d. Borax.—Borax is the mildest alkali in common use in developers and is used only in negative developers. It is especially desirable in fine-grain developers where excessive softening of the emulsion must be avoided. Although a weak alkali, it can be used in very small amounts as an accelerator because it is in the class known as buffer alkalies. This means that only a small portion of the alkali is released at any one time. However, as these small portions are used up, more is released until the reservoir of supply is exhausted. For this reason, developers using borax as an accelerator have the faculty of being able to develop a quantity of emulsions before showing noticeable signs of exhaustion. Ordinarily, it is impossible to dissolve sufficient borax in a solution to take the place of a stronger alkali.

e. Sodium metaborate.—This alkali (trade name, Kodalk) is similar in its reaction to borax, and while a stronger alkali than borax, it is not so strong as sodium carbonate. It is used only in developers for negatives and it is claimed that its use minimizes the danger of chemical fog and eliminates any possibility of the formation of gas bells. Sodium metoborate or Kodalk should be used only in formulas in which it is specified.

f. Paraformaldehyde (*trioxymethylene*).—This alkali is a solid which contains 30 percent formaldehyde. It is used only in process developers where the most extreme contrast is necessary. A developer containing paraformaldehyde must be used at an exact temperature and will even then exhaust rapidly. However, when properly used, it gives superior results. When in a developing solution, the paraformaldehyde combines with the sodium sulfite to form sodium hydroxide which then acts as an accelerator.

33. Restrainers.—Potassium bromide, potassium iodide, and sodium chloride are the three chemicals which are generally used as restrainers in developers. Of these three chemicals potassium bromide is the most used. Some reducing agents require more restrainer than others and while there are a few developing solutions used which do not include a restrainer, most developers will not function properly unless one is included as an ingredient.

a. Ordinarily a developer without a restrainer will act as follows:

(1) Development will be rapid and inclined to develop an image formed near the surface of the emulsion.

(2) Some of the unexposed as well as the exposed silver halides will be reduced. This will show as chemical fog.

(3) The developed image will be lacking in contrast.

(4) The emulsion, especially a print emulsion, may show slight yellow stains.

(5) The tone or color of a print will be a bluish black.

b. When potassium bromide is added to the developing solution, it is difficult for the developing agent to reduce the exposed silver halides and even more difficult to reduce the crystals which are not exposed. After the potassium bromide has been added, the solution will act as follows:

(1) Development will be slower, especially in the less exposed areas.

(2) Chemical fog will be diminished.

(3) The contrast will be increased because of the greater restraining action in the less exposed areas.

(4) The probability of stains will be decreased.

(5) The image of a print will be composed of greenish-black silver although prolonged development will cause the silver to become more nearly black.

c. Potassium iodide has a much greater restraining action than potassium bromide. It is seldom found in formulas for developers but it is most effective for eliminating chemical fog and abrasion marks in photographic printing papers. Increased amounts of potassium bromide will eliminate a reasonable amount of chemical fog in paper; however, the prints will have a greenish tone, whereas potassium iodide will render bluish-black tones. Sometimes the use of a combination of the two will result in prints pure black in color. As the restraining action of potassium iodide is so pronounced, care must be exercised that an excessive amount is not added to the developer. Its use also necessitates prolonged fixation since silver iodide which forms in the emulsion fixes much slower than silver bromide. Prints developed in a developer containing potassium iodide will stain when inspected in a strong light unless they have been fixed for about 2 minutes.

d. Sodium chloride is seldom found in formulas for developers, but like iodide, is sometimes used in developers for defective emulsions. It is desirable as an extra restrainer in print developers in that it causes little change in the color of the print.

34. Keepers.—A solution composed only of a developing agent and water will deteriorate in a length of time varying according to the kind of agent. This deterioration consists of oxidation, which in this case is an absorption of oxygen from the air and from the water, and this oxidizing action eventually makes the solution unfit for developing purposes. Developing agents will not oxidize in an acid condition, so a slightly acid chemical is added to the solution. Such a chemical is called a "keeper." Sodium bisulfite is one of the most common chemicals which perform this action. The three acidified sulfites, sodium metabisulfite, also called pyrosulfite, potassium metabisulfite, and sodium bisulfite are the chemicals usually used as keepers in developers. Citric acid and oxalic acid are also used as keepers.

35. Preservatives.—The difference between a preservative and a keeper is that a keeper prevents oxidation of the solution until it is used, while the preservative prevents excessive oxidation while it is being used. In one-solution developers, the preservative also acts as a keeper.

a. Sodium sulfite is the chemical most commonly used as a preservative. In fact there are seldom any chemicals other than sodium sulfite and sodium bisulfite used as preservatives.

b. By regulating the rate of oxidation of the developing agent, the sulfite not only preserves the developer, but regulates the color of the image and prevents stains and fog. Another characteristic of the preservative is that it prevents excessive softening of the emulsion when it is in high concentration in a developing solution. The action of the preservative in a developer is opposite to that of the accelerator.

c. When in use in a developing solution, sodium sulfite absorbs oxygen and forms sulfonates. This change also occurs in weak solutions of sodium sulfite and of the anhydrous form upon prolonged exposure to the air. To prevent this, sodium sulfite should be mixed in concentrated solution and should not be procured in large containers.

36. Exhaustion of developing solution.—As a rule, when a developing solution is exhausted it becomes discolored, gradually turning yellow, brown, or milky. The degree of exhaustion is indicated by the amount of discoloration. The formation of bubbles on the surface of the solution also indicates exhaustion.

a. When development is done by inspection, a noticeable increase over the normal time of the appearance of the image is proof of exhaustion. When the time and temperature method is used for developing, an exhausted developer will cause weak images.

b. It is impossible to state precisely the number of negatives a developing solution will develop as it is dependent upon many factors, among which are the dilution of the solution, the amount of exposed silver in each emulsion, and how long a time the developer is subject to oxidation.

37. Summary.—From the above explanation of the functioning of developing solutions and the part each ingredient serves in the functioning of the combined solution, it is evident that a photographic developer must be an accurately balanced solution. An increase in the amount of one ingredient necessitates an increase in the amount of another ingredient or a decrease in the amount of yet another to preserve the balance of the solution. It should be further noted that the dilution of a developing solution has a marked effect on the manner in which it works. Negatives and prints of high quality can be made only when developed in a solution compounded from a formula which has been found suitable for the type of emulsion. This formula should be used as long as it proves satisfactory as it is poor practice to change from one formula to another. There are times, however, when variations in the manufacture of an emulsion, differences in water, or climatic changes will necessitate the modification of the formula or a change to an entirely different formula. These modifications and changes should be avoided as much as possible.

Section V

FIXATION

38. Functions of fixing baths.—*a.* The three functions of fixing baths are to—

(1) Stop development.

(2) Make the image permanent by removing unexposed silver halide.

(3) Harden the gelatin in the emulsion.

b. The acid in a fixing bath accomplishes the first function, the second is effected by means of a chemical (called the silver solvent) which is capable of removing the unexposed silver halide of the emulsion, and an emulsion hardener or toughener performs the third function.

39. Chemicals used in fixing baths.—The following chemicals are used to perform the above functions:

a. Silver solvents.—Sodium thiosulfate and ammonium chloride.

b. Emulsion hardeners (tougheners).—Potassium alum (white), (potassium aluminum sulfate), potassium chrome alum (potassium chromium sulfate), and formalin (40 percent solution formaldehyde).

c. Acids.—Acetic acid, sulfuric acid, boric acid, and acidified sulfite (sodium bisulfite).

d. Preservatives.—Sodium sulfite and acidified sulfite.

40. Stopping development in fixing baths.—*a.* Most of the exposed silver halide in an emulsion is changed into metallic silver during development. When a film is removed from a developing solution, the developer within the emulsion and on its surface will continue developing the remaining exposed silver halide. An emulsion is always rinsed after it is removed from the developing solution and before it is placed in the fixing bath. This removes the surface developer and a considerable portion of that which lies deep in the pores of the emulsion which to a great extent stops development. However, unless an acid rinse bath is used, there is still enough developing solution remaining in the deeper pores of the emulsion that development of the remaining exposed silver halide will continue. This continuation of development shows in the form of irregular areas of added density.

b. The acid in a fixing bath will immediately neutralize the alkali of the developer which is retained in the emulsion when it is placed in the fixing solution. As a developer will not oxidize in an acid state, there can be no continuation of development. By preventing oxidation of the developer, the acid will also assist in preventing oxidation stains in the emulsion.

41. Making the image permanent.—*a.* Ordinarily when an emulsion is exposed, there is a considerable portion of the silver halide unexposed. The amount of unexposed silver halide in an exposed emulsion depends upon the nature of the subject and the amount of exposure. In many instances, the number exposed is less than half of the total crystals in the emulsion. Besides these unexposed silver halide crystals, there is usually a considerable portion of the exposed silver halide in a developed emulsion which has not been reduced to metallic silver by the developer.

b. This surplus silver halide eventually will become discolored by exposure to light and the quality of the photograph will deteriorate. Therefore, before any photographic image can be considered permanent, all of the unused silver halide and exposed silver halide must be removed from the emulsion.

c. Silver halides whether exposed or unexposed are insoluble in water. Before they can be washed from an emulsion, they must be treated with some chemical which will form a soluble compound of silver. The chemical generally used to create this change is sodium thiosulfate which changes the undeveloped silver salts to complex silver salts of silver sodium thiosulfate, which are soluble.

42. Hardening of emulsion.—*a.* In the process of development, the gelatin of the emulsion becomes softened by the action of the alkali in the developing solution. As soon as development is completed, it is essential that the emulsion is hardened sufficiently so that it can be fixed, washed, and dried without damage to the emulsion. Without hardening, the emulsion is subject to abrasions, scratches, blisters, frills, reticulation, or even complete melting of the emulsion. Reticulation is the wrinkling of the surface of an emulsion into a network.

b. This hardening of the emulsion can be secured by placing it either before or after development in a solution which is capable of hardening (or tanning) the gelatin. These solutions are called supplementary hardening baths and the chemical used to harden the gelatin is usually alum.

c. It is more customary to combine hardening with fixation. Therefore, most fixing baths include some form of alum as a hardening agent.

43. Preservative in a fixing bath.—*a.* When an acid is added to a solution of sodium thiosulfate, the acid will decompose the sodium thiosulfate and the solution will liberate sulfite and sulfur. When sodium sulfite is added to the solution, the decomposition will continue but the acid will combine with the sulfite and form new hypo. When too much acid or insufficient sulfite is present in a fixing bath, this reforming of the hypo will not occur and the solution will become sulfurous and unusable as will be revealed by the milky appearance of the bath.

b. A second function of the preservative in a fixing bath is to prevent oxidation of the developer which is carried into the solution. Although the acid in a fixing bath will stop most of the oxidation of this developer, a slow oxidation will take place which will cause stains unless a preservative is included in the solution. Sodium sulfite (or sodium bisulfite) in a fixing bath will combine with oxidized developing agents to form complicated and colorless compounds (mono-sulfonates and disulfonates) and in this manner prevent oxidation stains.

44. Plain fixing baths.—*a.* A plain fixing bath is composed of hypo and water. The normal strength is a 25 percent solution. A gallon of 25 percent solution contains about 2 pounds of hypo and will test 68 by hydrometer when the temperature of the solution is 65° F.

b. A 40 percent solution of hypo will react with silver halides faster than a solution of any lesser or greater strength. Solutions stronger than 30 percent are seldom used because when emulsions are fixed in strong solutions of hypo, the emulsion will blister and frill when placed in the wash water. This occurs more often when the wash water is warm. These defects can be prevented by placing the fixing emulsion in a weaker solution of hypo for 2 or 3 minutes before removing it to the wash water, but this will not prevent a second difficulty which is encountered when concentrated solutions of hypo are used. When light strikes an emulsion which is being fixed in a solution of hypo stronger than 30 percent, an insoluble residue of dichroic silver is deposited on the emulsion.

c. Because plain fixing baths do not immediately stop development, they are seldom used for fixation except when an acid rinse bath is also used. It is necessary to use plain fixing baths in some of the after treatments given emulsions as when using some bleachers, reducers, and intensifiers. Plain fixing baths are used as the foundation for other types of fixing baths.

45. Acid fixing baths.—*a.* An acid fixing bath is a plain fixing bath with the addition of a preservative and an acid but does not contain a chemical to harden the emulsion. A satisfactory acid fixing bath can be made by adding about 4 ounces of sodium bisulfite to 1 gallon of 25 percent hypo solution. A more stable fixing bath can be made by adding to each gallon of 25 percent solution of hypo 3.2 ounces of sodium bisulfite and 1.3 ounces of sodium sulfite.

b. Sodium bisulfite is acidified sulfite, and while the acid content is not great, it is sufficient to assist in stopping development when it is used in a fixing bath. The sulfite prevents oxidation of the developer and the decomposition of the hypo by the acid. Acid fixing baths are more suitable for use with prints than they are for negatives. They are recommended for fixing prints either when it is not necessary that the emulsion of the prints be hardened or when an intermediate hardening bath is used. As the acid content of the acid fixing bath is slight, an acid rinse bath should be used to rinse prints before they are placed in the solution.

46. Acetic acid hardening fixing baths.—*a.* An acid hardening fixing bath is the most used type. This solution is used for fixing either prints or negatives.

b. The ingredients of the acid hardener are water, sodium sulfite, acetic acid, and potassium alum (white). The amounts of sodium sulfite and potassium alum are usually equal. An acid hardening bath can be prepared by adding to a 25 percent solution of hypo the desired amount of the acid hardener. The ratio of the acid hardener can be varied to secure any desired degree of hardening, but it is better practice to use the same ratio of hardening solution and vary the amount of alum. Any decided increase in the amount of alum indicated in a formula should be avoided since it is seldom necessary to use more alum but frequently necessary to use less.

47. Boric acid hardening fixing baths.—*a.* A boric acid hardening fixing bath consists of a plain fixing bath to which has been added a hardener solution composed of water, sodium sulfite, potassium alum (white), acetic acid, and boric acid.

b. Boric acid in a fixing bath extends the time in which the bath will retain its hardening properties. Any fixing bath will eventually precipitate a sludge of aluminum sulfite. When the sludge appears, the solution must be discarded. By extending the time the solution can be used before sludging occurs, the boric acid prolongs the life of a fixing bath. Boric acid fixing baths will usually remain clear throughout their useful lives or until the time of clearing an emulsion of milkiness is at least double that required with a fresh bath.

48. Chrome alum fixing baths.—*a.* Because of their staining action, chrome alum fixing baths cannot be used for prints. As a rule, they are used only under tropical conditions of temperature. In extremely hot weather and especially hot damp weather, it is sometimes found that other types of acid hardening fixing baths do not harden the gelatin sufficiently. Potassium chrome alum has greater hardening action on gelatin than potassium alum (white).

b. A chrome alum fixing bath consists of a plain fixing bath to which has been added sodium sulfite, potassium chrome alum, and either sulfuric or acetic acid. Chrome alum fixing baths lose their hardening properties more rapidly than other types of acid hardening fixing baths.

49. Tropical fixing baths.—While a chrome alum fixing bath will prove quite satisfactory for fixing negatives under tropical conditions, equal or superior results can be obtained by using a boric acid hardening fixing bath, provided the negatives to be fixed are first treated in a hardener rinse solution containing potassium chrome alum and sodium sulfate.

50. Rapid fixing baths.—*a*. Ammonium chloride is one of the few chemicals besides hypo which is used as a silver solvent in fixing baths. This chemical is classified as a rapid fixing agent, although when used alone it will not dissolve silver halide as rapidly as hypo. If ammonium chloride is combined with hypo in correct proportion, the combination of fixing agents will react faster than when either is used alone. A bath of this type will fix a negative in about 1 minute, if used at a temperature of 75° F.

b. An ordinary acid hardening fixing bath will fix a negative in about 1½ minutes when heated to 80° F. This rapid fixing bath is more convenient than an ammonium chloride hypo bath and is highly satisfactory for the purpose.

51. Time of fixation.—Time of fixation varies with different emulsions. Cloride emulsions will fix more rapidly than bromide emulsions and bromide print emulsions will fix faster than most negative film emulsions. It is customary and amply safe to fix films twice as long as it takes them to clear. This assures that the sodium silver thiosulfate has reached a soluble as well as a transparent state.

a. When a photographic emulsion is not thoroughly fixed, it is impossible to wash the unused silver halides from an emulsion and the emulsion will eventually stain and fade. There is also a possibility that the emulsion will not be sufficiently hardened.

b. When an emulsion is left in a fixing bath for a too long period of time, the solution will bleach out some of the more scattered silver grains. This bleaching action will be most noticeable in the shadow areas of negatives and in the highlights of prints. The loss of a very small amount of shadow detail in a negative will make a decided difference in the quality of a print made from the negative. Likewise a faint loss of highlight detail in a print will lower the quality of the print considerably. Prolonged fixation of emulsions will also cause excessive hardening of the gelatin and will prevent prints from taking a high gloss when they are ferrotyped.

52. Use of double fixing baths.—*a.* When processing either negatives or prints, the trays or tanks used for fixing baths are considerably larger than those used for the developing solutions. This is necessary because the fixation of emulsions usually requires considerably more time than developing which causes large numbers of negatives or prints to accumulate in the fixing bath. Instead of having one large tray or tank to contain the fixing bath, it is much better practice to use a double bath.

b. The emulsions are removed from the developer, rinsed, and placed in the first fixing bath for the first half of the fixing time. They are then removed to the second bath for the final period of fixing. The neutralizing of the developer and most of the changing of the silver salts into silver thiosulfate is accomplished in the first bath. If this first bath is in good condition, it will probably do 80 or 90 percent of the work done by the two baths. As the first bath does most of the work, it will become exhausted before the second bath shows any signs of exhaustion. The first bath should be discarded, the second bath moved into the position of the first bath, and a fresh first bath mixed for the final stage of the fixing process. The theory of working double fixing baths in this manner is that while the first bath does most of the work, if it does not accomplish its share of fixation the second bath will, because of its freshness, assure complete fixation. The first bath must not be allowed to become exhausted as there is a chance of securing spotted emulsions caused by continuation of development by oxidation stains.

c. The use of double fixing baths not only assures complete fixation but also makes it easier to keep emulsions in batches which saves time and assures more uniform fixation. This system of fixing emulsions is particularly desirable in quantity production.

53. Capacity of fixing baths.—*a.* Ordinarily, the capacity of a fixing bath is measured by the number of prints or negatives of a certain size which it can be depended upon to fix. This refers to the solvent capacity of the hypo. While the ability of a fixing bath to stop development, to harden the emulsion, and to dissolve the silver should exhaust uniformly, it is not always possible to achieve this in actual practice. For instance, a large number of white background prints would exhaust the fixing power of a bath before its power to harden the emulsion or to stop the development was spent. Several times as many dark prints, such as reproductions of blue prints, would exhaust the hardening power of a fixing bath before the fixing power was exhausted. Emulsions rinsed in plain water rinse baths will exhaust the hardening power of a fixing bath much faster than those which have been rinsed in acid rinse baths. However, the hardening properties of boric acid fixing baths are seldom exhausted before the fixing capacity has been reached.

b. A gallon of fixing bath of average concentration should fix about fifty 8- by 10-inch negatives or sixty 8- by 10-inch prints. If an acid rinse bath is used with the prints, the capacity of the fixing bath can be doubled. If an intermediate hardener is used in processing negatives, the capacity of the fixing bath is also increased.

c. While it is good practice to know the tentative capacity of fixing baths and to keep an approximate record of the number of prints or negatives which have been processed in a fixing bath, it must be remembered that the estimated capacity of a fixing bath is an approximation and that when the appearance of a bath indicates that it is becoming exhausted, it should be discarded.

54. Testing acid hardening fixing baths for exhaustion.—*a*. There are several simple tests for determining whether a used fixing bath is exhausted. While any one of these tests used singly is not a conclusive test, several used together will indicate its true condition. These tests are—

(1) *Frothiness.*—Bubbles will form on a fresh fixing bath when the solution is agitated. However, the bubbles will be comparatively few and of small size and will break rapidly. An exhausted fixing bath will form more and larger bubbles which are hesitant to collapse.

(2) *Milkiness.*—A milky bath is exhausted.

(3) *Sludging.*—When a milky sludge (aluminum sulfite) forms it indicates exhaustion of the bath.

(4) *Feel.*—A fresh fixing bath will feel "grippy" to the fingers while an exhausted bath will have a "slimy" feel.

(5) *Test strips.*—These give a comparison of the known time it takes a fresh bath to clear a strip of undeveloped film with the time it takes a used bath to clear a similar strip. When the time for clearing in the used bath is double that of the fresh bath, the solution is exhausted.

(6) *Iodide test.*—To 10 parts of the fixing solution to be tested, add 1 part of a 4 percent solution of potassium iodide. If the fixing solution is exhausted a milky precipitate will be formed.

b. The above tests for exhaustion of fixing baths should be considered but in case of doubt as to the usability of a fixing bath, it should be discarded. The cost of the chemicals used to fix a negative is only a fraction of a cent. The cost of fixing a print properly is even a smaller fraction of a cent. It is poor economy to take a chance on spoiling several dollars worth of sensitized material by economizing on fixing solution.

55. Acid rinse bath.—While water is the simplest form of rinse, there is danger that development will continue during the rinse and even after it is placed in the fixing bath. The use of an acid rinse bath prevents these difficulties and increases the capacity of the fixing bath.

a. A common acid rinse bath, or stop bath, for prints is a 1½ percent solution of acetic acid. When prints are removed from the developer, they can be placed directly into the acid rinse bath. It is better practice to rinse the prints momentarily in water and then place them emulsion up in the acid bath. The prints should be left in the acid rinse bath for at least 5 seconds. If desired, they may be allowed to accumulate for as long as 10 minutes. This will permit the fixing of the prints in batches which not only saves time but will assist in uniform fixing. Provided prints are first rinsed in running water, this bath has a capacity of about sixty 8- by 10-inch prints per 100 ounces of solution. When an acid rinse bath becomes deeply discolored or when bubbles begin to form around the edges of the tray, it should be discarded. If acid rinse baths are used, it is possible to fix from 50 to 100 percent more prints in a fixing bath than when water alone is used for rinsing.

b. A suitable rinse bath for negatives is a 2½ percent solution of sodium bisulfite which will stop development and help preserve the fixing bath but will not harden the emulsion.

c. Intermediate hardening baths are more often used than rinse baths for negative emulsions. They are a combination rinse bath and hardening bath. An ounce of potassium chrome alum in 32 ounces of water is a standard solution for an intermediate hardening bath. It is good practice to use a bath of this type in all negative processing, but it is most important that it be used when negatives are developed in developers which are strongly alkaline, especially if the negative is to be fixed in a fixing bath of higher than normal acid content. This hardening solution should also be used when the gelatin is abnormally soft after development. Failure to use an intermediate hardening bath when any of the above conditions prevail will probably result in the formation of gas bells during the process of fixation. Gas bells are caused by too rapid chemical reaction between the alkali of the developer in an emulsion and the acid of a fixing bath. This chemical reaction forms a gas in such quantity that being unable to escape through the pores of the emulsion, it raises the emulsion from its support and forms minute blisters. A solution of chrome alum will neutralize the developer in an emulsion to some extent and will harden the emulsion sufficiently that gas bells will not form when the negative is placed in a fixing bath. Negatives should be placed in this bath, agitated for at least 5 seconds, and left in the bath for from 3 to 5 minutes. This bath when mixed is a blue-violet color, and when exhausted is a yellow-green color. Sometimes a used chrome alum rinse bath will precipitate a sludge. When this occurs the bath should be discarded since it is most difficult to remove a deposit of this sludge from the surface of the negative.

56. Supplementary hardening baths.—*a.* Whenever the emulsion of prints appear too soft, they should be placed in a supplementary hardening bath. This bath is a dilute solution of the potassium alum hardener solution used in the acid hardening fixing bath. This bath is often used for hardening prints after toning by the redeveloping process which invariably softens the gelatin of emulsions. Prints to be dried by belt dryers are often treated in a supplementary hardener so that indentations of the weave of the cloth belt will not be made in the emulsion. Prints are treated in a supplementary hardener for 5 minutes and washed in three changes of water after removal from the hardener solution.

b. Negative emulsions are seldom treated in supplementary hardening solutions. However, when negative emulsions become softened excessively as they often do from certain processes of intensification and reduction, they can be rehardened with a solution containing water, formalin, and sodium carbonate. When hardened sufficiently, the negatives should be rinsed and fixed for 5 minutes in an acid fixing bath.

SECTION VI

WASHING NEGATIVES AND PRINTS

57. Importance of sufficient washing.—*a.* Negatives and prints must be washed for a considerable time after fixation to wash the chemicals of the fixing bath and the sodium silver thiosulfate from the emulsion. The washing must be prolonged because of the spongelike structure of the gelatin coating. It requires time for the water to permeate and free the emulsion from the chemicals. If these chemicals are allowed to remain in the emulsion from imperfect or insufficient washing, they will in time act upon the metallic silver image and convert it to one of another color or completely fade or obliterate it.

b. Most film negatives are backed with a layer of gelatin. During the fixation of a negative, the gelatin backing as well as the emulsion becomes impregnated with the fixing solution. This solution also penetrates the fibers of the paper base of prints. A negative or print to be permanent must have all the chemicals of the fixing bath and the soluble silver completely eliminated; it is more difficult to wash the chemicals from the paper base of a print, especially a double weight print, than from the emulsion.

58. Importance of proper fixation.—*a*. When an emulsion is properly fixed, the undeveloped silver halides are changed into a soluble compound of silver. A portion of this soluble salt goes into solution with the other chemicals composing the fixing bath and the rest is removed by washing the emulsion in running water.

b. The thickness of the gelatin layer composing the emulsion is decreased by the hardening action of the fixing bath. This facilitates the removal of the chemicals from the pores of the gelatin since it is difficult to wash chemicals from gelatin which is abnormally soft. The emulsion requires proper fixation to be sufficiently hardened.

59. Theory of washing.—The theory of washing can be explained by following what happens in the washing of one 8- by 10-inch negative. A negative of this size, when removed from a standard fixing bath and placed in a tray of water, will carry about 3 drams of the fixing solution into the wash water. This amount of fixing solution will contain about 40 grains of hypo and a proportionate amount of the other chemicals of the fixing solution. When an emulsion has been washed sufficiently to remove the hypo, these additional chemicals are also eliminated.

a. When a negative is placed emulsion up in a tray of water, the hypo will diffuse from the emulsion into the water. This action will continue until there is an equal concentration of hypo in the emulsion and in the water immediately above the emulsion surface. The concentrated solution is heavier than water and will lie in layers of different densities. Agitation of the water will equalize the concentration throughout the solution and thereby allow more chemicals to diffuse from the negative into the water. Continually changing the water will lower the concentration of hypo, and the washing is considered complete when there is only $\frac{1}{100}$ of 1 percent solution. However, at least theoretically, each square inch of the emulsion would contain 0.033 milligrams of hypo. An emulsion containing this quantity of hypo would not be permanent. Two additional changes of water would reduce the amount of hypo remaining in the emulsion to such an extent that it will be permanent provided it is not subjected to extremely adverse conditions. Therefore, 12 complete changes of water are usually considered sufficient for washing emulsions. A complete change of water may be considered as one which involves a complete draining of the previous water, the use of a reasonable quantity of water at a temperature of 60° to 70° F., leaving the emulsions in the water from 3 to 5 minutes and including at least a slight amount of agitation of the emulsions during that time.

b. Although negatives and prints could be washed in the above manner using relatively small amounts of water, the necessary time is reduced by using more water, either by washing in a series of changes or by using a continuous flow. It has been proved that one complete change of water removes one-half the undesirable chemicals from a negative or print. A second change of water will eliminate one-half the remaining chemicals and after a third water there will be retained in the emulsion only one-eighth of the original amount of chemicals. This explains the necessity of making the first three washings thorough. When the amount of chemicals remaining in a negative or print emulsion is halved in each successive change of water, at the end of 10 changes there will remain only $1/1024$ of the original amount of chemicals. After 12 changes of water theoretically there would remain in the emulsion only about $1/4100$ of the chemicals which it contained at the beginning of the washing period. This small fractional part of the chemicals remaining in a negative or print will not have a deleterious effect on the image.

c. Tests have proved that in washing, it is much more difficult to eliminate chemicals from prints than it is from negatives because the fibers of the paper base tenaciously retain the chemicals. This is more pronounced with double-weight prints than single-weight prints. For this reason the working directions for washing negatives and prints specify a certain time for negatives, a longer time for single-weight prints and a yet longer time for double-weight prints.

60. Methods of washing.—The following methods of washing are direct applications of the theory of washing:

a. Washing in trays.—Both prints and negatives are often washed in trays. While washing can be accomplished by using one tray, it is better practice to use two trays, changing the emulsions from one tray to another and emptying the water from each tray each time the emulsions are removed to the other tray. Another method used to wash negatives and prints in trays involves the use of a siphon. The siphon is designed so that when it is attached to the edge of the tray, fresh water is fed to the surface, while the heavier chemically contaminated water is siphoned from the bottom. Whichever method is used in washing negatives in trays with running water, the negative should be agitated at intervals.

b. Washing in tanks.—When tanks are used for washing, negatives are placed in metal frames and suspended in a vertical position in the tank. By this method the chemicals diffuse from the negatives and sink to the bottom of the tank, and if the tank is properly designed the heavier solution drains from the bottom. The metal frames hold the negatives apart, allowing the wash water to be in constant contact with both emulsion and back side of each negative.

c. Mechanical washers.—The most efficient method of washing prints is to use a mechanical washer which has facilities for spraying fresh water in the top and siphoning the chemically contaminated water from the bottom. The prints to be washed are placed in a cage which is revolved either by the force of the entering water or by a motor. The movement of the cage together with the water spray causes the prints to change their position constantly during the washing time. As fresh water is continually flowing into the tank while the used water is being siphoned from it, a few minutes are required to secure a complete change of water. For this reason, it is advisable to rinse prints in two or three changes of water before they are placed in the washer.

61. Hypo test solutions.—*a.* Hypo test solutions are used to test prints and negatives to determine whether they have been sufficiently washed. One method of testing is to remove several prints or negatives from the wash water allowing small quantities of water to drain from them into a few ounces of a weak solution of potassium permanganate. If there is only a trace of hypo in the emulsions, the permanganate solution which is a light pink color will change to a lemon color. If the prints or negatives contain a considerable amount of hypo, the solution will become colorless.

b. A superior test solution is composed of water, sodium hydroxide, and potassium permanganate. When negatives or prints are allowed to drain into this solution, a trace of hypo will cause the color to change from violet to orange. The presence of more hypo in the water will cause it to change from an orange to a yellowish-green color. About 30 seconds should be allowed for the changes in color to occur. However, the same changes in color will sometimes occur because of the presence of oxidizable organic matter in the water used for washing. To avoid any discrepancy in the test, it is advisable to use distilled water for the solution and mix twice the quantity of testing solution needed for the test. Using one-half the solution, perform the test as directed above. If discoloration occurs, it may be caused from either hypo or organic matter in the wash water. To test the water, place an amount of plain tap water equal to the quantity of water drained into the first solution in the second half of the testing solution. If there is discoloration in this second half, it indicates that there is organic matter in the tap water. If no discoloration occurs, it is proof that the discoloration in the original test was caused from hypo. The tap water used should not be taken from the container in which the prints are being washed because there would be no indication of its purity.

c. The above two methods test the amount of hypo in the water which is only an indication of how much is remaining in the emulsion. There are several tests which can be used to determine the amount of hypo remaining in the emulsion. One of these involves treating the emulsion with a solution containing mercuric chloride and potassium bromide. This test, when accurately performed, will determine the presence of hypo in an emulsion when the amount is as small as 0.005 milligrams per square inch. An even more satisfactory method for testing involves the use of silver nitrate. Experiments have been made which showed that an emulsion apparently free from hypo, when tested in an alkaline solution of potassium permanganate, was proved by the silver nitrate test to contain 0.02 milligrams of hypo per square inch. The silver nitrate test is performed as follows: Process, with the prints to be tested, an unexposed sheet of *white* photographic paper. (The same weight and size of the majority of prints in bath are used.) After the final wash, cut off a strip of this sheet and immerse it in a 1 percent silver nitrate solution for about 3 minutes. Rinse the strip and compare, while wet, in subdued daylight or artificial light, with the *wet* untreated portion. If the hypo has been completely removed, no color difference can be observed. A yellow-brown tint indicates the presence of hypo. However, the presence of hydrogen sulfide or wood extracts in the water supply will sometimes cause the same tinting of the test strip even though the hypo has been eliminated from the emulsion.

d. Hypo eliminators.—Objections are often made to the use of hypo eliminators in photography. These objections are based on the fact that it is often as difficult to remove the chemicals of the eliminators, or the compounds which are formed by these chemicals, from the emulsions as it is the hypo and that these chemicals when remaining in emulsion will be equally as harmful as hypo. However, the following two treatments have been found to work satisfactorily:

(1) *First method.*—Recommended for negatives. Wash negatives 8 to 10 minutes. Treat in 0.3 percent solution of ammonium hydroxide, using distilled water for mixing for 2 minutes. After this treatment wash for 2 minutes. Although ammonium hydroxide is superior, sodium hydroxide or sodium metaborate can be used at the same percentage strength.

(2) *Second method.*—Wash double-weight prints for 20 minutes. A shorter washing time can be used for single-weight prints, after which place the prints for 5 minutes in the following eliminator solution:

Water	10	ounces.
Hydrogen peroxide (3 percent solution)	16	ounces.
Ammonia (3 percent solution)	3¼	ounces.
Water to make	32	ounces.

After treatment in the above solution, the prints should be washed for 10 minutes. One gallon of this hypo eliminator is sufficient for treating eighty 8- by 10-inch prints. This eliminator can also be used for negatives providing it is diluted about 1 to 10. Stronger concentration than this will soften and blister negative emulsions.

SECTION VII

REDUCTION AND INTENSIFICATION OF NEGATIVES

62. General.—Although the photographic technician constantly strives to make perfect negatives, there are many negatives made which must undergo special treatments before they can be satisfactorily printed. These special treatments are known as reduction and intensification.

63. Types of negatives for treatment.—*a.* The following types of negatives can be improved by intensification or reduction:

(1) Flat.
(2) Foggy.
(3) Contrasty.
(4) Dense.
(5) Thin.

b. Such negatives are the result of incorrect exposure, improper development, faulty emulsions, or sometimes by either the natural contrast of the subject itself or by the nature of the light in which the negative was made. Of the above types of negatives, some may be improved by intensification while others must be reduced. It is better photographic practice to retake a defective negative than to reduce or intensify it, but there are times when it is impracticable or even impossible to expose a second negative. Before subjecting a negative to either of these treatments, it is recommended to make first the best possible print from the negative. Then in case of damage to the negative in the treatment, a copy negative can be made from the print and this negative used as a substitute.

64. Reduction.—Reduction is often considered as the opposite of developing because when a negative is reduced the image is chemically dissolved, while in development the image is built up by means of chemicals. The need for reduction varies according to the image characteristics in the negative. There are three types of reducers in general use which will fit almost any need.

a. Subtractive or surface cutting reducers.—This type of reducer is used for flat negatives and principally those which show an excessive amount of shadow detail or fog in the shadows. Theoretically, a surface cutting reducer removes an even layer of silver from the upper part of the image. This removal of a thin layer from the entire surface of an image will reduce the amount of fog and shadow detail and will increase the contrast of the negative. In practice, the reducing action is more apparent in the shadow areas than in the clearer portions, probably because the silver grains are more widely separated in the shadow areas.

(1) *Farmer's reducer.*—The most common subtractive reducer is Farmer's reducer, which consists of a solution of plain hypo to which has been added, immediately before use, a sufficient amount of a strong solution of potassium ferricyanide to change the solution to a deep lemon color. When treated in this solution, the silver is converted by the ferricyanide to silver ferrocyanide, which is dissolved by the hypo in the solution. The solution of ferricyanide may be kept as a stock solution, but the hypo solution deteriorates rapidly after the ferricyanide is added.

(*a*) When a negative which has been dried is to be treated in Farmer's reducer, it should first be thoroughly soaked. If it is to be treated after immediate removal from an acid fixing bath, it should first be rinsed in several changes of water. After the negative has been reduced it must be washed for 30 minutes in running water.

(*b*) Probably the most satisfactory use that can be made of a ferricyanide reducer is to reduce the fog that often shows in the transparent areas of negatives of line drawings. Either slight overexposure or overdevelopment will often cause the lines and letters of these negatives to be slightly foggy. This fog can be completely removed by placing the negative in a solution of Farmer's reducer which affects the heavier densities more slowly.

(2) *Permanganate reducer.*—This is a subtractive reducer which is applicable when reducing pyro-stained negatives. A ferricyanide reducer will produce additional stain on a stained image, while a permanganate reducer will reduce the amount of stain in the image as well as reducing the metallic image.

(*a*) A solution of potassium permanganate has only a very limited power to reduce silver. Such a solution is sometimes used to remove a very slight fog from a negative. For most purposes, sulfuric acid (C. P.) is added to the permanganate solution, greatly increasing its reducing action.

(*b*) The emulsion of a negative reduced in a permanganate reducer often becomes highly stained with a brownish stain. This stain can be removed by placing the negative in a weak solution of sodium bisulfite.

(*c*) When potassium permanganate is used, acidified with sulfuric acid, part of the silver which forms the image is converted into silver sulfate which, being soluble, is washed from the emulsion by the water in the reducing solution. After reduction is complete the negative should be rinsed, treated in a weak solution of sodium bisulfite, and placed either in a freshly made plain or acid fixing bath.

b. Superproportional reducers.—Superproportional reducers reduce more silver in the highlights of a negative than in either the halftones or the shadows. Having this characteristic, it may be seen that a superproportional reducer reduces contrast. Dense highlights can be reduced with no apparent reduction taking place in the less dense areas of the negative.

(1) An acidified solution of ammonium persulfate is the only reducer which will reduce in this manner. One theory which has been advanced to explain why an ammonium persulfate reducer will dissolve silver grains which lie together in rather compact masses more than grains which lie apart, is that the silver grains which form the high lights of a negative contain some silver bromide, while the more scattered grains are more nearly pure metallic silver.

(2) A slightly acidified solution of ammonium persulfate will change the silver composing the highlights of a negative into silver

sulfate which goes into solution in the reducer in the same manner as it does in a permanganate reducer. However, this silver sulfate, when in solution, speeds up the action of the reducing solution, and if reduction is not controlled, will reduce the halftones and shadows of the negative.

(3) It is difficult to obtain ammonium persulfate of uniform purity and strength. For this reason, the action of this chemical in reduction is somewhat erratic. Difficulties will be lessened if a good brand of ammonium persulfate is secured in reasonable quantities and in small size containers.

(4) In using this reducer, the negative should be removed from the solution before the reduction has reached the degree desired as a slight amount of reduction will continue before the action can be stopped. This applies to some degree in using all types of reducers. When removed from the reducing solution, the negative should be rinsed hurriedly and placed for a few minutes in a 2 percent solution of sodium bisulfite or fixed in a fresh acid fixing bath.

c. Proportional reducers.—A proportional reducer is one which reduces the silver of a negative in amounts proportionate to the quantity of silver forming the different densities of the negative. Proportional reducers are used to reduce dense negatives which have normal or excessive contrast. Since, when using a proportional reducer, amounts of silver are removed which are proportionate to the different densities, the contrast of the negative is decreased. This decrease in contrast is beneficial in treating negatives having excessive contrast as well as excessive density, but is detrimental when treating negatives of normal contrast. Unless it is necessary to make a large number of prints from a dense negative or it is desired to make projection prints which would require prohibitively long exposures, it is better practice to utilize the extra time in printing a dense negative than it is to reduce it in a proportional reducer.

(1) One type of proportional reducer is made by combining a subtractive reducer with a superproportional reducer. The subtractive reducer reduces the shadows and also slightly reduces the halftones, while the superproportional reducer reduces the highlights and has little reducing action on the halftones. Such a solution can be made by combining in a solution the proper amounts of potassium permanganate, ammonium persulfate, and sulfuric acid.

(2) After a negative is treated in this solution it should be hurriedly rinsed, placed in a 1 percent solution of sodium bisulfite for a few minutes, and washed without fixing.

(3) Proportional reduction of negatives can be conveniently secured by bleaching a negative in the bleaching solution of a chromium intensifier and only *partially* redeveloping the image in a dilute metolhydroquinone developer. The developer used should not contain an excessive amount of sodium sulfite. After redeveloping to the desired degree the negative is fixed in an acid fixing bath and washed.

d. Local reduction.—Local reduction is the reducing of a portion or portions of a negative. It is accomplished by applying the solution to the area to be reduced by means of a wad of cotton or a brush. The negative should be soaked in water and supported on a piece of glass. The solution is applied to the negative carefully to avoid affecting any area which it is not desired to reduce. To prevent the spreading of the solution, the negative should be rinsed often. Local reduction requires considerable practice and skill, but it is well worth while to become proficient in this process because negatives can be greatly improved by its use. Any type reducer can be used for local reduction, but the ferricyanide reducer is the most satisfactory.

65. Intensification of negatives.—Intensification is a chemical treatment for increasing the density or contrast of a negative. It is most important that before intensification a negative be thoroughly fixed. When there is doubt as to the completeness of the fixation of a negative it should be fixed in a fresh fixing bath for 10 minutes and washed 30 minutes. Since most intensifiers tend to soften the gelatin, it is advisable to harden the negative before it is intensified. This is accomplished by placing it in the following solution:

Formalin (37 percent formaldehyde)	2½	drams.
Sodium carbonate (desiccated)	73	grains.
Water to make	32	ounces.

Treat the negative for 3 minutes in this solution. Wash the negative for 10 minutes and then immerse it in a 2 percent solution of acetic acid. This acid rinse will prevent uneven action of the intensifier. It is preferable to intensify the negative without drying. Only one negative should be intensified at a time and the negative should be constantly agitated throughout the entire process.

a. Intensifying solutions.—These solutions may be divided into three types according to the method used to increase the opacity of the silver grains which form the image. The three types are:

(1) Intensifiers which will cause some metal to combine with each silver grain.

(2) Solutions which will change silver grains to a different color. This color must be such (usually brown or red) that paper emulsions will be less sensitive to the light which has passed through the negative.

(3) Solutions containing nitrate of silver which will cause additional silver to deposit on the original metallic image.

b. Types of negatives suitable for intensification.—The following types of negatives can be improved by intensification:

(1) Flat negatives having weak shadow details. A negative of this type would be the result of overexposure and underdevelopment.

(2) A negative of a flat subject, especially when the subject was illuminated with a flat light. A negative made under these conditions will be lacking in contrast and density.

(3) A process negative of a line drawing or similar subject which has insufficient density in the denser areas of the negative. This lack of density would be caused by either underexposure or underdevelopment of the negative.

c. Ingredients used in intensifiers.—Compounds of gold, silver, platinum, lead, copper, uranium, and other metals are used as ingredients in intensifiers. The metal of any of these compounds will combine with the silver grains of a negative to produce a strengthened image. Compounds of mercury, chromium, and silver are the most frequently used.

d. Intensification action of intensifiers.—In selecting the kind of intensification process to use it should be known that they vary primarily in the degree of intensification, rather than in any marked differences in action. The only differences in action which should be considered are slight variations in the solvent power on the weaker parts of the image. Some of the processes tend to dissolve out the shadows while strengthening the shadow portions, whereas others will build up each density of the negative proportionately to its original density. Each of these two types of reducing action will increase the contrast of the negative.

e. Mercuric bromide intensifiers.—Mercury intensifiers are used more than any other type. They are most satisfactory but have one weakness in that a negative intensified with mercury is very likely to stain after a few years. When permanence is essential, a chromium intensifier should be used.

(1) The bleacher of a mercuric bromide intensifier is a solution containing mercuric chloride and potassium bromide. A negative to be intensified by this process must be thoroughly fixed and washed. The negative is placed in the solution and left until the black of the image disappears. After the bleaching of the negative is complete,

it is essential that the chemical of the bleaching solution be completely removed from the emulsion before the negative is treated in a redeveloping solution. This can be accomplished by washing in running water for at least 20 minutes or by placing the negative for a few minutes in three successive baths of weak hydrochloric acid.

(2) The image can be redeveloped in any of the following solutions, each of which gives a different degree of intensification:

(*a*) A 10 percent solution of sodium sulfite. This solution gives the least intensification, forms an image of doubtful permanency, and gives superproportional intensification.

(*b*) A weak M. Q. developer. Gives more intensification, image not permanent, inclined to soften gelatin.

(*c*) 10 percent ammonia. Uneven and superproportional intensification and inclined to soften the gelatin.

f. Mercuric iodide intensifier.—This type intensifier has two distinct advantages: First, it is not necessary that the negative be washed completely before intensification, and, second, intensification can be stopped at any desired point. The single solution mercuric iodide intensifier contains equal parts of mercuric iodide, potassium iodide, and hypo, dissolved in water. This solution can be used repeatedly until exhausted. Should intensification be carried too far, the intensification can be reduced or removed entirely by placing the negative in a 20 percent solution of hypo. This must be done before subjecting the negative to any after-treatment. After the negative has been removed from the intensifying solution, it should be washed for 30 minutes. When permanence is essential, the negative must be placed in a metol-hydroquinone developing solution or a 1 percent solution of sodium sulfide. After either of these treatments, the negative must be thoroughly washed.

g. Chromium intensifiers.—This type intensifier makes a permanent image. It is desirable because a moderate amount of intensification can be secured by one treatment of the negative. A greater amount of intensification can be secured by repeating the process. However, the process should not be repeated more than once. The bleaching solution contains potassium bichromate, hydrochloric acid, and water. Before being placed in the bleaching solution the negative must be hardened in a formalin hardening solution. After the negative has been thoroughly bleached, it is washed for 5 minutes and then redeveloped in a metol-hydroquinone developer. The developer used must be one which does not contain an excessive amount of sodium sulfite. The redeveloping should be in subdued daylight or artificial light, and will require from 3 to 10 minutes, depending upon the degree of intensification desired. After redevelopment the negative is rinsed, placed in a fixing bath for 5 minutes, and then washed thoroughly. Greater intensification can be secured by repeating the process.

h. Reduction and intensification.—There are negatives which can be improved by treating them in both reducing and intensifying solutions. When both treatments are to be given, it is the best practice to reduce the negative before intensifying it. This double treatment for the whole negative is seldom necessary, but negatives are often both locally reduced and locally intensified.

i. Local intensification.—A negative can be locally intensified by applying intensifying solutions with a wad of cotton or a brush to the parts of the negative which require intensification.

SECTION VIII

TONING

66. General.—Toning in photography means changing the color of the black silver forming the image of a motion-picture film, lantern slide, or print. Although the color can be changed to green, blue, red, brown, or shades of these colors by the use of proper solutions, only the chemistry and some of the formulas involved in making sepia prints of black and white prints are included herein.

67. Sepia toning processes.—Sepia toning processes are divided into two general classifications, direct and indirect. In direct processes, the image of the print is converted directly to silver sulfide which is a sepia or brown color. In indirect processes, the black image is first converted to silver bromide or silver chloride, both of which are a yellowish color. This is called bleaching the print. The yellow silver forming the image is then changed into silver sulfide by placing the print into a solution of sodium sulfide.

68. Hypo alum toning process.—The hypo alum toning bath is preferable for use when there is sufficient demand for sepia prints.

a. Advantages of toning prints by the hypo alum method over the bleaching and redeveloping processes are:

(1) It is easier to secure uniform tones and to match prints made at different times.

(2) The prints need not be washed after fixation and may be transferred from the fixing bath directly to the toning bath.

(3) On the average, prints on chloride or bromochloride paper tone better by this method.

b. Disadvantages of using the hypo alum method are:

(1) The bath must be used at a temperature of about 120° F.

(2) It necessitates the use of a double boiler arrangement to be used satisfactorily.

(3) The prints must be swabbed after toning.

c. The hypo alum bath contains hypo, potassium alum (white), sodium chloride, and silver nitrate. Some baths also contain gold chloride and are called hypo alum gold toning baths. New baths will not work until ripened by running through some discarded prints. In actual practice, it is not customary to mix an entirely new bath, the used bath being strengthened when necessary by the addition of some fresh solution. The prints tone in from 7 to 10 minutes, the lighter portions of the prints toning first and the shadows last. When the black has disappeared, the toning is complete and all the silver has been converted to silver sulfide.

69. Redeveloping process.—This process is preferable when sepia toning is not a daily practice and when the prints to be toned are likely to be printed on different papers. This process gives better results than the hypo alum method with prints made on bromide paper. This is a two-solution process, the first solution containing potassium bromide, potassium ferricyanide, and sometimes aqua ammonia. This bath changes the silver image to silver ferrocyanide which is then changed to silver bromide. After a thorough rinsing, the print is placed in a solution of sodium sulfide which changes the silver bromide to silver sulfide. In the first solution, the prints will bleach in a few minutes and in the second solution they will redevelop in a few seconds.

70. Prints suitable for sepia toning.—*a.* It is rather difficult to describe the ideal black and white print for sepia toning. Prints on different papers act differently in toning and there is a difference of opinion as to what color is most desirable in a sepia print. Some photographers prefer what are called cold tones and others, warm tones. Cold sepia tones are brown with a blue or purple tinge and warm sepia tones are brown with a yellow tinge. A true sepia tone, however, is a rich brown having a slightly reddish tinge, the same color as furnished for sepia in water colors or oil paints.

b. In spite of the diversity of opinion as to the ideal color of sepia prints, the following facts relating to the black and white print can be relied upon:

(1) The print should be a few shades dark, not because it will bleach in sepia toning, but because a brown image is lighter than a black image.

(2) If possible, the print should be a trifle contrasty, as the contrast from white to the darkest brown of the sepia print is not so great as from white to the darkest shadow of the black and white print.

(3) Prints should be fixed in fresh fixing baths. If not completely fixed, they will show degraded whites, especially if toned by the redeveloping process.

(4) The developer used should have less than the normal amount of potassium bromide.

(5) Prints should be fully developed, but not forced.

(6) Papers having a soft contrast are inclined to yield cold sepia tones, and papers having a hard contrast yield warm tones.

(7) Cold prints (blue-black) give cold sepias.

(8) Warm prints (those having a green or olive tone) give warm sepias.

(9) Prints having many dark areas appear better sepia-toned than those having considerable sky or other light areas.

(10) The subject should be one which would logically appear in a brown color. Portraits, especially those on dark backgrounds, and landscapes, particularly autumn scenes, are appropriate for sepias. A picture of a pile of coal or a snow scene would not be proper in sepia color as coal is naturally black and snow does not have a brown cast.

(11) Prints to be toned by the redeveloping process should be completely washed. If not, the hypo remaining in the print will combine with the ferricyanide and cause bleaching of the print.

Section IX

CHARACTERISTICS OF CHEMICALS USED IN PHOTOGRAPHY

Paragraph

71. General.—The important facts concerning each photographic chemical are correct name, general appearance, solubility, proper method of handling, and proper storage. Some chemicals have several names, but the common name for each should be remembered. Chemicals are supplied properly labeled and are best stored in their original bottles or containers, making sure the label is securely attached to the container. The label often includes terms such as Chemically Pure (C. P.), Commercial, or U. S. P., which indicates the strength or purity of the chemical. A chemically pure chemical is one which is as pure as it is possible to manufacture. A commercial chemical is one of weak strength or not of the highest grade of purity. However, some commercial chemicals are used for photographic purposes.

72. Appearance.—Some chemicals have distinctive appearances that can be easily remembered, but others have the same general appearance which make obvious the necessity of always keeping all chemicals properly labeled. Distinctive physical characteristics may be peculiar colors or shapes of crystals in the case of solids, or distinctive colors, odors, and apparent heaviness or lightness in the case of liquids.

73. Solubilities.—A definite amount of a chemical can be dissolved in a given amount of water at a specified temperature. This amount varies with different chemicals, being quite large in the case of some and extremely small with others. The amount that can be dissolved usually increases as the temperature of the water is increased. When all the chemical that can be dissolved has been taken up by the solvent, the solution is a saturated solution. This is the basis of solubility tables. In photographic work, solubility tables are based on temperatures at 40° and 70° F. A list of chemicals used in photography which includes their solubilities at the above temperatures is given in appendix II.

74. Care in handling.—A few of the chemicals used in photography are deadly poisons and many others are slightly poisonous. Still others are caustic or corrosive. All chemicals should be handled with extreme care.

75. Solid chemicals.—*a.* A solid chemical may be in the form of a powder, grain, or crystal. A chemical in crystal form contains water of crystallization. An anhydrous or desiccated chemical contains no moisture. A few chemicals used in photography are monohydrated. A monohydrated chemical contains more moisture than a dry chemical but less than it contains in a crystal form. Formulas usually specify the strength of the chemical listed when it is available in more than one form. If a different form is substituted, allowance must be made for the difference in strength of the two chemicals.

b. Some chemicals in the form of crystals will deliquesce or effloresce. A deliquescent chemical is one which absorbs moisture from the air. An efflorescent chemical gives off moisture. As the strength of these chemicals varies according to the amount of moisture they have absorbed or lost, they should be stored in a place where the air is of normal humidity.

76. Liquid chemicals.—A number of the chemicals used in photography are liquids. Liquid chemicals will sometimes expand with heat sufficiently to cause leakage in their containers. Certain liquid chemicals will solidify at low temperatures. For these reasons, liquid chemicals must not be stored where they will be subjected to extremes in temperature.

77. Percentage solutions.—Many formulas specify that a certain quantity of a definite percentage solution be used. To make 100 ounces of a percentage solution, weigh out a number of ounces of the chemical equal to the number or percent desired and add water to make 100 ounces of solution. Different quantities can be made by using proportional amounts of chemicals and adding water to proportional amounts. The method for mixing percentage solutions from liquid chemicals is explained in appendix I.

78. Stock and working solutions.—A stock solution is a concentrated solution; that is, the minimum quantity of water is taken when it is prepared so that when it is used it is diluted with water according to directions. The diluted solution is called the working solution. Solutions are made concentrated in order to save labor in preparation, to economize in the number of containers, and to make them stable in storage. A given quantity of a stock solution that must be diluted with water for use will last longer than the same quantity of a solution prepared ready for use. Moreover, the concentrated solution may be cooled or heated to the required working temperature by being diluted with water which is warmer or colder than the stock solution. However, when small quantities of a solution are prepared for immediate use, a working solution is usually made up.

79. Temperature of solutions.—The directions for using a photographic solution usually state that the solution will accomplish a certain result in a given time at a specified temperature. When the solution is used at a higher temperature, the result will be accomplished in a shorter period of time, while if the solution is used at a lower temperature it will require a longer time to cause the same amount of chemical reaction.

a. Specified temperatures.—(1) Directions for using developing solutions usually specify temperatures of 65° F. for developers for negatives and 70° F. for developers for prints. There are some print developers for which a temperature of 65° F. is specified.

(2) The temperature for fixing baths is usually either 65° F. or 70° F., but it is the best practice to use the temperature which coincides with that of the developer.

(3) Hardening baths, intensifiers, reducers, bleaching solutions, etc., are generally used at temperatures of 65° to 70° F., although the temperature may not be specified.

(4) Solutions to be used in tropical photography are often used at temperatures as high as 90° or 95° F. These high temperatures can be used only because provision is made for additional hardening of the gelatin of the sensitized emulsions treated in the solutions. Temperatures as high as 85° F. are often used in rapid development and rapid fixation. Emulsions can be treated in solutions of high temperature as they are in the solutions for only short periods of time. The highest temperature at which any solution is used in photography is 120° F., which is the temperature of the hypo-alum toning bath and for making sepia prints. The gelatin of prints properly hardened in the fixing solution will withstand this temperature.

b. Maintaining temperature.—The best method of maintaining solutions at the correct temperature is to have the room temperature the same as that of the solutions. When this cannot be done, the following may be practiced:

(1) Use larger quantities of solutions.

(2) Place trays or tanks in utensils containing large quantities of water a few degrees warmer or colder than the temperature of the solution.

80. Mixing solutions by hydrometer.—*a.* Hydrometers measure specific gravity, which is the ratio of the weight of a substance to the weight of an equal volume of water at the same temperature. When a chemical is dissolved in water, the specific gravity is increased. The measurement of specific gravity then presents a simple method of measuring the concentration of a chemical in water. The hydrometer is generally calibrated to indicate specific gravity, but quite often its calibration is intended to indicate the concentration of a definite chemical in water. The most common method of using a hydrometer is to know beforehand the specific gravity of the required concentration and to add a chemical to water until the necessary reading is obtained. A standard temperature is generally used in hydrometer measurements, which should be maintained wherever possible since higher temperatures lower specific gravity and lower temperatures raise it.

b. Formulas often specify that solutions of hypo, sodium sulfite, sodium carbonate, and other chemicals be mixed to a concentration that will give a specified hydrometer test. While a hydrometer can only be used to test a solution containing one chemical, it is an accurate method of mixing solutions. No consideration need be given as to whether the chemical dissolved is in a desiccated, monohydrated, or crystal form, or as to the degree a chemical has deliquesced or effloresced.

81. Photographic formula.—To prepare a photographic solution, it is necessary to have a formula for such a solution. This formula may be memorized, but if the solution calls for chemicals in exact amounts, it is not safe to depend upon memory but to have a written copy of the formula as a guide for the operations necessary to prepare the solution. The ingredients and the amounts to be used are stated. Amounts are expressed according to a standard system of weights and measures. The formula to be followed should be for the volume of solution desired and in the system of weights and measures that is to be used. The avoirdupois system of weights and the United States standard liquid measure are often used although many formulas are written in the metric system. Tables of weights and measures are included in appendix III.

82. Use of scales.—*a.* Two types of balance scales are available for weighing chemicals. The small size is used for weighing small amounts of chemicals, usually not more than a few ounces, while the larger size is used for weighing larger quantities.

b. The spilling of chemicals on parts of scales should be avoided. Scales should be kept dry and clean and in accurate adjustment. The pan or scoop on which the chemicals are placed should be protected by a piece of paper to avoid contamination. A paper of a size which will balance this protecting paper must be placed on the opposite side of the scales. When the paper holding the chemical is emptied it should be folded, with any clinging chemicals inward, and disposed of in such a manner that there is no chance of chemical dust contaminating the air.

83. Liquid measure.—*a*. The required quantity of a fluid is measured in a graduated container which has marks on the side indicating the capacity of the vessel and smaller units of liquid measure. The extent of such graduations varies according to the total capacity of the graduate and its design, there being small-sized graduates which are finely divided into fractions of a fluid ounce and larger graduates in which it is not possible to measure less than an ounce or half ounce.

b. Sometimes a formula calls for a certain number of drops in a solution. The ordinary type of eye dropper, procurable at any drug store, is the most convenient device for measuring drops. When using an eye dropper, it should be held in a horizontal position to secure large and uniform drops.

84. Water suitable for photographic purposes.—*a*. Water comes in various states of purity, the purest form of which is distilled. Distilled water is not necessary for photographic purposes if the water obtained from natural sources does not contain impurities harmful to photographic work.

b. The impurities that may be present in various kinds of water are dissolved salts, such as bicarbonates, chlorides, and sulfates of calcium, magnesium, sodium, and potassium. If calcium salts are present in the water and a developer is prepared containing sodium bisulfite or potassium metabisulfite, fine needle-shaped crystals of calcium sulfite will precipitate in the developer while it is standing. This precipitate is harmless and will settle to the bottom, but the developer is nevertheless deprived of sulfite in the amount required to form the sludge. If the developer is agitated, the sludge will cause trouble by settling on the emulsions of the sensitized materials. If iron is present to any great extent, the water should not be used for photographic purposes. Near the ocean, sodium chloride may be present in water, which will exert a restraining action in the developer. This may be offset, however, by adjusting the quantities of the other ingredients in the developer.

c. Dissolved salts often cause trouble by crystalizing on the film of a negative after drying; and although not always visible as crystals to the eye, they detract from the transparency of the negative.

d. Water may also contain suspended matter in the form of dirt and iron rust, which if not filtered out and allowed to settle, will cause spots on the negatives developed in solutions prepared with it. It may also contain slime consisting of animal or vegetable colloidal matter which cannot be removed by filtering. If such water is used for preparing photographic solutions, the colloidal matter coagulates gradually and settles as a sludge.

e. Water in some localities contains dissolved gases such as air, carbon dioxide, or hydrogen sulfide.

f. Water may be purified as follows:

(1) *Distillation.*—Distilled water should be used for mixing solutions whenever it can be obtained easily. However, a still of adequate capacity is expensive and the process of distillation is slow.

(2) *Boiling.*—This coagulates the colloidal matter and changes certain lime salts to an insoluble condition in which they then settle out, while dissolved gases such as air, hydrogen sulfide, etc., are removed. Therefore, unless the water contains an excessive amount of dissolved salts, it is usually sufficient to boil the water and allow it to settle.

(3) *Chemical treatment.*—This is the most practical method if large quantities of water are required. The following methods of chemical purification may be used:

(*a*) Add alum to the water in the proportion of 15 grains to a gallon. This coagulates the slime which carries down any suspended particles and the solution rapidly clears. This method does not remove dissolved salts and the small amount of alum introduced into the water has no harmful effect on the developer.

(*b*) Add a 10 percent solution of sodium oxalate which precipitates calcium and magnesium salts and coagulates the slime, although the sodium and potassium salts are left in solution.

(*c*) Hydrogen sulfide can be eliminated from water by adding to each gallon of water 60 grains of lead acetate.

85. Containers suitable for mixing and storing solutions.—Containers made of the following materials are suitable for mixing and storing solutions: glass, enameled steel, 18-8 molybdenum stainless steel, hard glazed stoneware, and hard rubber. A container of a size and shape permitting stirring of the solution without spilling must be selected for mixing. The container used for storing a solution should be of a size that can be completely filled and should have a stopper or suitable cover.

86. Preparations for mixing solutions.—Before starting mixing operations, check the supply of hot water and chemicals and have the necessary containers, funnels, graduates, stirring rods, thermometer, hydrometer, and scales available for use. All apparatus which is used in mixing operations must be reasonably clean.

87. Water for mixing.—Most formulas specify the amount and temperature of the water to be used in mixing a solution. In some formulas, only the total amount is given and there is no temperature specified. A sufficient amount of water should be used to insure proper dissolution of chemicals so that very little water need be added after the chemicals are dissolved to complete the amount of solution. Too much water, however, will make stirring difficult.

a. When a formula does not specify the temperature of the water, it is usually correct to use the water at tap temperature. In other cases, knowledge of the characteristics and quantities of chemicals to be used must be employed. Pyro must not be dissolved at a temperature of more than 100° F. Temperature of 125° F. is safe for dissolving metol and hydroquinone.

b. The Fahrenheit temperature scale is commonly used in photography. Another system which is often used is known as Centigrade (C.). On the Centigrade scale, water freezes at 0° and boils at 100°, and on the Fahrenheit the corresponding readings are 32° and 212°. There are definite formulas for use in converting one scale to the other, as follows:

$$C=\frac{5}{9}(F-32)$$

$$F=\frac{9}{5}C+32$$

88. Order of mixing.—*a.* Unless otherwise stated in the formula, the ingredients called for must be dissolved in the order given. Most formulas list the ingredients in that order. However, it may happen that the order of listing the ingredients does not conform with the order in which they should be dissolved. In such case, the photographer is expected to know the proper order of mixing.

b. The correct order for mixing a developer is as follows:

(1) Dissolve the preservative first. In the case of metol, dissolve

only a portion of the sulfite first, dissolve the metol, and then the remainder of the sulfite.

(2) Make sure that one chemical is dissolved before adding the next. If the carbonate or alkali is added before the crystals of the developing agent are dissolved, the crystals will begin to oxidize at the surface and the resulting solution will give fog.

(3) Mix solutions at as low a temperature as possible.

(4) Always pour dry chemicals into water and not vice versa.

(5) When adding water to make the total desired amount of solution, it is always permissible to add cold water.

89. Stirring.—As a solid is added, the water or solution is stirred thoroughly to expedite its dissolving throughout the solution. The solid is poured in a little at a time and a suitable stirring rod is employed. The kind of rod in ordinary use is made of vulcanized rubber, which is chemical proof. For a large tank, a large stirring rod is necessary which is often made of wood in the form of a paddle. It is best to coat such wooden paddles with paraffin and to use a paddle for one kind of solution only.

90. Filtering.—It is not good practice to filter a solution unless it is absolutetly necessary, since the process of filtration adds too much air to the solution. It may happen, however, that solutions contain foreign particles which should be removed and this is best done by filtration. The most effective kind of filtering is through filter paper. This comes in circular sheets of different diameters suiting the size of the funnel to be used. To place the paper in the funnel, fold it twice so as to form a quarter section and open one loop and the result is a pointed cone which should be inserted, point downward, in the funnel. The liquid to be filtered is poured into the cone. A less effective method of filtering is through clean cloth such as white muslin, or a good grade of raw absorbent cotton. Solutions used for processing miniature films are often filtered because of the danger of foreign particles causing spots on the negatives, which, even though minute, cause noticeable defects when enlarged.

91. Amount of solution to mix.—Some solutions used in photography must be used immediately after mixing so that only enough for use should be mixed. Although there are a few solutions which will keep almost indefinitely, it is not considered good practice to mix solutions in quantities which will not be used reasonably soon. Most solutions, especially fixed baths, will have better keeping qualities when stored at temperatures not higher than 70° F.

CHAPTER 4

SENSITIZED MATERIALS

SECTION I

GENERAL

92. Properties.—This chapter includes a description of the various factors which determine the suitability of sensitized materials for specific purposes. Each type of emulsion has definite photographic and physical properties which have been incorporated in its manufacture to fulfill a particular photographic need. The photographic properties for any sensitized material include color sensitivity, contrast, speed, and graininess. Physical properties refer to antihalation and noncurling features which are functions of the backing, type of base on which the various emulsions are coated, surface texture, and other special properties.

93. Classification.—In general, photographic materials may be classed as either negative or positive. Negative materials refer to those on which a negative image is best obtained. Positive materials are generally used in conjunction with negatives to obtain positive images, although there are special emulsions on which a positive image is obtained directly after exposure to light by direct positive or "reversal" processing. Reversal film, natural color film, and direct positive papers are included in the latter classification.

SECTION II

PHYSICAL PROPERTIES

94. Emulsion.—The general physical properties of an emulsion are thickness, melting point, irradiation, and processing effects.

a. Thickness.—Negative emulsions are usually comparatively thick for the purpose of obtaining satisfactory exposure latitude. Positive emulsions coated on a transparent base are normally thinner and reversal emulsions are much thinner. This is to insure complete highlight exposure throughout the emulsion, producing clean and brilliant pictures. Positive emulsions on paper are extremely thin in order to afford rapid processing of prints and to give a clearly defined image by reflected light.

b. Melting point.—Photographic emulsions have a certain degree of hardness which determines the rate of penetration of solutions used in processing. The average melting point of all emulsions is about 105° to 110° F. but some special emulsions have higher melting points. Ordinarily, the highest safe temperature for processing an emulsion is about 20° F. below the melting point to avoid undue softening. Too much hardening will decrease the swelling and consequently the penetration rate of the different processing solutions. For obvious reasons, in hot climates it is necessary to have a higher degree of hardening than normal.

c. Irradiation.—A photographic emulsion before development is considerably turbid. Thus, when light is incident upon it, there is a considerable amount of internal reflection or scattering of light within the emulsion which causes a spreading of the image thereby lowering its definition. This effect is called "irradiation." The image spread is proportional to the exposure for a particular emulsion but it is negligible except when the exposure is exceedingly great.

d. Processing effects.—The gelatin of an emulsion swells to different extents during processing, but on drying, it shrinks to very nearly its original size. This effect is reduced to a minimum if temperatures of the various solutions are normal and constant.

95. Support for the emulsion.—The material selected as a support for a photographic emulsion must possess several important qualities. It must be photographically inert; that is, unable to cause a deleterious action on the emulsion, on the latent image, or on the silver grains of the developed image. It must also be unaffected by the solutions used in processing. There are many substances which are suitable, but the most common are cellulose derivatives, glass, and paper.

a. Cellulose derivatives (film base).—The most commonly used supports for negative emulsions are composed of cellulose acetate and cellulose nitrate. These materials are especially suitable because they are strong, lightweight, transparent, and flexible. Film base of cellulose acetate is most often preferred because of its low inflammability. The thickness of the film base varies according to the type of film and the manner in which it is used. Roll film, for example, must be more flexible than cut film and have a thinner base.

b. Glass.—Glass has been largely superseded by the introduction of cellulosic film, but is still used for special applications where rigidity and absolute freedom from swelling or shrinking are important. Other advantages are that it is practically photographically inert and transparent. However, it has the disadvantages of weight, bulk, fragility, and nonflexibility.

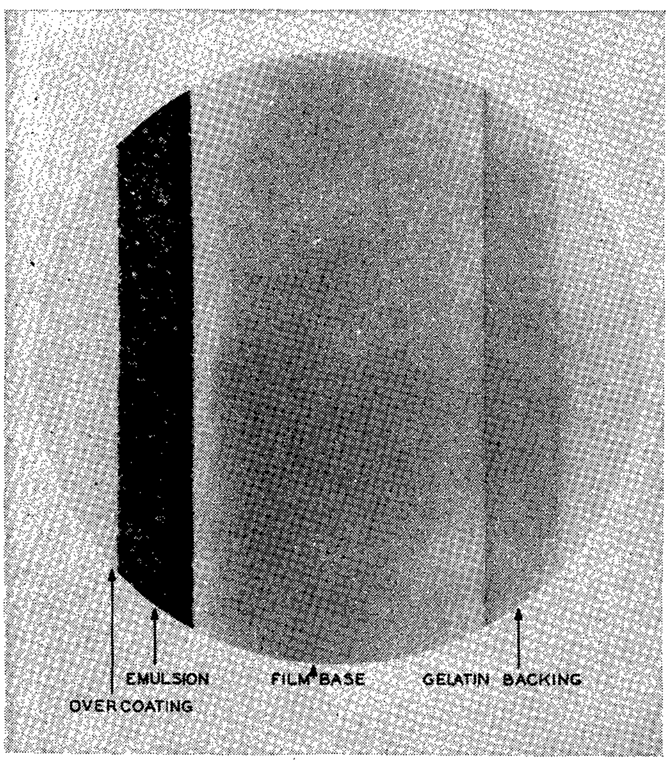


FIGURE 5.—Cross section of film.

c. Paper.—Paper is an ideal support for prints because it is flexible, opaque, economical, and durable. Photographic papers vary in thickness and surface texture according to their use.

96. Protective coatings.—Additional layers of some substance are often included in the manufacture of photographic materials for protective purposes. Some papers have thin coatings of waterproof lacquer over the base for rapid processing and drying. In order to prevent scratches and abrasions during handling, emulsions are often given a top coating of clear gelatin. The film base of aerial films is often especially prepared to minimize the effect of shrinkage (fig. 5).

97. Noncurl backing.—An emulsion on film will swell when wet and shrink when dried, producing a strain which causes the material to curl. To prevent this, a gelatin coating is often included on the back of the base which will swell and shrink in the same manner as the emulsion, thereby lessening the effective curl of the material.

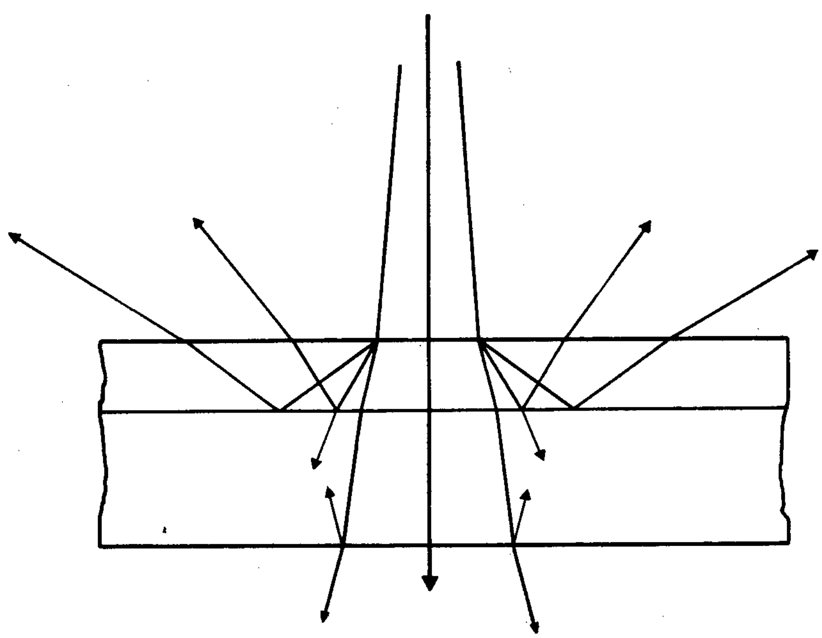


FIGURE 6.—Halation.

98. Antihalation backing.—Light which passes through an emulsion and into the base at an oblique angle is reflected from the rear surface of the base and reenters the emulsion. This produces a bright halo of light around the image and is called "halation." It can be prevented by placing some substance on the rear surface of the base which will absorb these light rays. This is accomplished either by dyeing the base gray so that the light is greatly reduced in intensity, or by dyeing the gelatin backing with a color to which the emulsion is not sensitive. The colored backing will absorb light and prevent its reflection into the emulsion. Both of these methods are used, depending upon the type of material and its use. The result is called "antihalation." (See fig. 6.)

Section III

CHARACTERISTICS

99. Color sensitivity.—Ordinary photographic emulsions are sensitive only to blue, violet, and ultraviolet light. Colored objects therefore are reproduced by an emulsion of this kind in very different values of brightness than those received visually. The addition of various sensitizing dyes to the emulsion extends the range of sensitivity of silver halide. Progressive discoveries of new dyes have increased the range to cover the complete visible spectrum and also the infrared region. By the proper choice of sensitizing dyes, an emulsion can be made sensitive to any particular region of the spectrum, visible or invisible. The sensitized emulsion thus can be manufactured for particular uses in photography. It is possible to make photographic exposures with the aid of light waves on either side of the visible spectrum. The photographic emulsion then is much more versatile than vision in its sensitivity to light. (See fig. 7.)

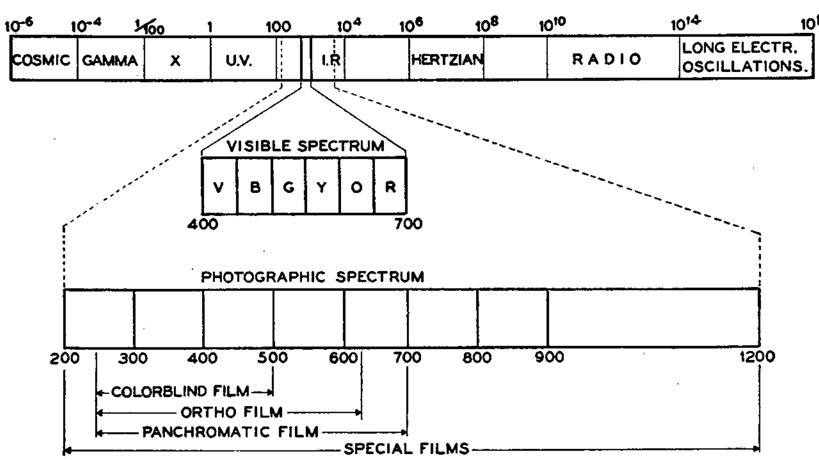


Figure 7.—Photographic spectrum.

100. Speed.—*a.* Emulsion speed is a measure of the sensitivity of the emulsion and determines the exposure necessary to produce the desired image. Speed is a measure of the rate of reduction of silver halide to subhalide. Expressions of speed are not in definite units but are relative to the various emulsions. For example, a common method of expressing speed is to select a slow material and consider its speed as unity. Other materials, then, would be given speed ratings depending upon how much faster or slower they would record an image in relation to the standard.

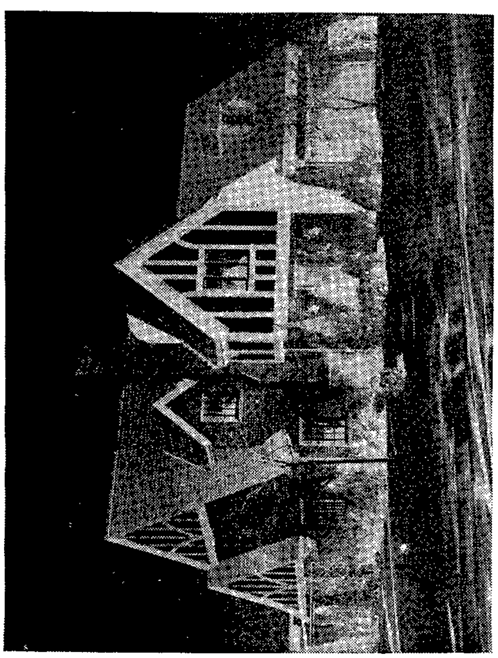
b. There are many factors which definitely influence the speed rating of an emulsion. The most important considerations in speed determinations are color sensitivity of the emulsion, spectral distribution of the light source, developer, and degree of development.

101. Contrast.—*a.* When a photographic emulsion is exposed in a camera, an image is registered. The chemical action of the light on the emulsion varies according to the light intensity. A great amount of light will affect a large number of silver halide particles and conversely a lesser number of particles will be affected by a small amount of light. Highlights are the brightest areas of the subject and create the most exposure on the photographic emulsion. Shadows in the subject produce less exposure. The difference in subject brightness from shadows to highlights is expressed as contrast. Photographically, contrast is that property of a photosensitive emulsion which determines the magnitude of density difference resulting from exposure differences. Figure 8 shows the range of brightnesses in a subject of normal contrast.

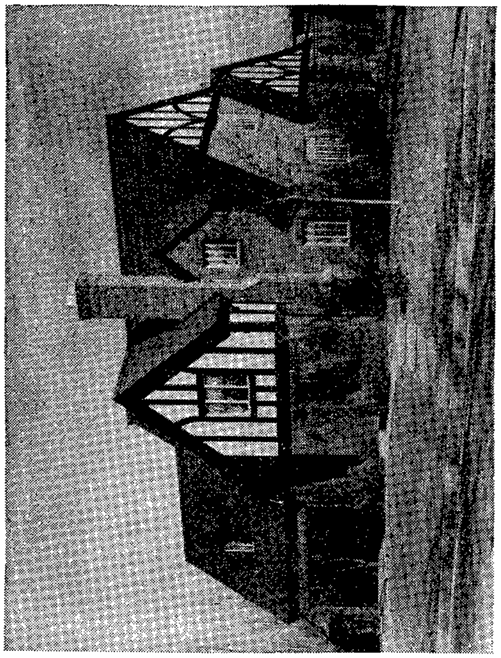
b. Contrast in photography primarily is a function of the emulsion but may be governed by other factors. In general, slow emulsions have high potential contrast and the faster emulsions lower contrast.

c. Other factors which influence image contrast are specific developers, degree of development, and subject contrast which may be varied with illumination.

102. Graininess.—*a.* A photographic image is composed of microscopic particles or grains of silver. With sufficient magnification, the image presents a granular appearance and when highly magnified the individual particles can be seen. The image has a grainy appearance when this granular effect is visible without magnification. The degree of graininess of an emulsion is partially dependent upon the original size of silver halide crystals before development. There is no definite measurement of graininess but it is an expression of comparison. Ordinarily, slow emulsions have fine grain and fast emulsions have coarse grain, with equal development. How-



① Negative.



② Print.

FIGURE 8.—Negative and print.

ever, by proper selection of developers it is possible to obtain fine grain with an originally coarse-grain emulsion. Originally fine-grain emulsions then would show proportionally finer grain with the same developer. Coarse grain in an image is generally caused by clumping of individual grains during development. Graininess, then, is largely a result of development. (See fig. 9.)

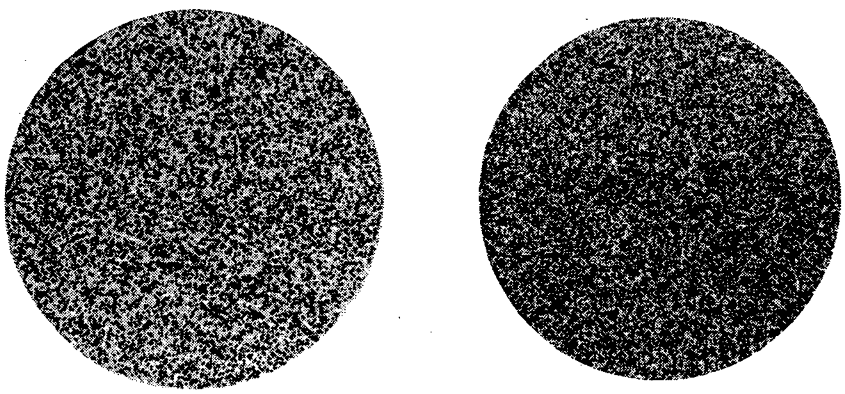
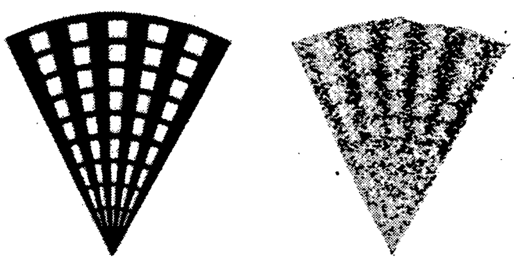


FIGURE 9.—Developed grains of coarse- and fine-grain emulsions.

b. The resolving power of an emulsion is a measure of its ability to reproduce fine detail. Coarse-grain emulsions tend to have low resolving power and fine-grain emulsions high resolving power. An emulsion of high resolving power will normally produce a sharply defined image. Resolving power is ordinarily expressed as the number of lines per unit of measurement which the emulsion can satisfactorily reproduce. For example, an emulsion of high resolving power may be capable of satisfactorily recording 100 lines per millimeter. (See fig. 10.)



① Test object. ② Enlarged image.

FIGURE 10.—Resolving power.

SECTION IV

NEGATIVE MATERIALS

103. Classes of color sensitivity.—Negative emulsions are divided into four general classifications as to color sensitivity; color-blind, orthochromatic, panchromatic, and infrared emulsions.

a. A color-blind emulsion (orthonon) is one which is not specifically sensitized to any color but has an inherent sensitivity to blue, violet, and ultraviolet. Color-blind emulsions may be manufactured in speed ratings from ultra-fast to extremely slow, but are usually of relatively slow speed and high potential contrast.

b. An orthochromatic emulsion is sensitive to ultraviolet and all visible colors except red.

c. A panchromatic emulsion is additionally sensitized to red. Panchromatic emulsions are subdivided into three main classes of color sensitivity as follows:

(1) Sensitive primarily to blue but somewhat less to green and red.

(2) Balanced sensitivity to all visible color (orthopanchromatic).

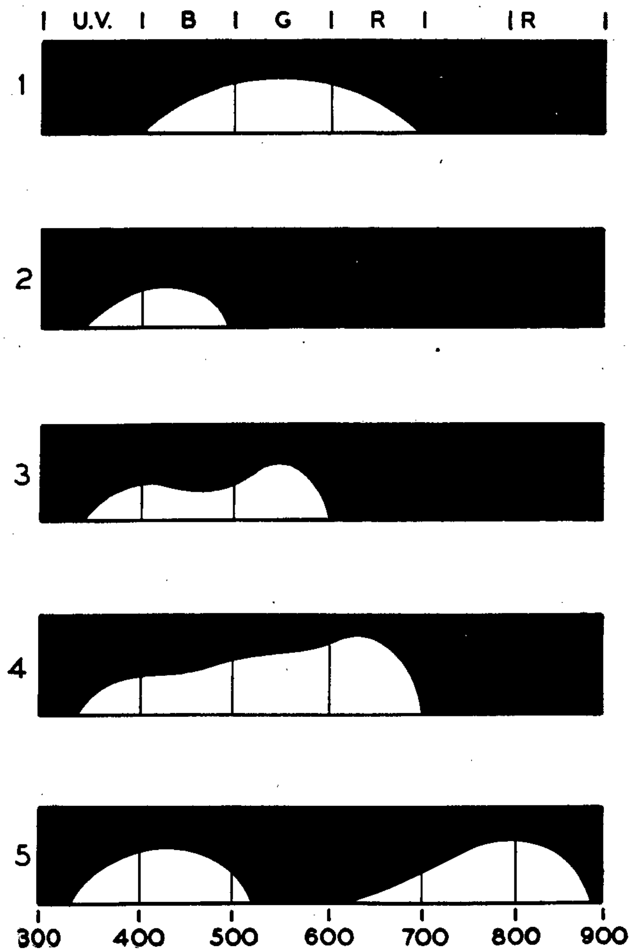
(3) Highly sensitive to red, equally sensitive to blue and green (hyperpanchromatic).

d. An infrared emulsion is not sensitive to green, yellow, or orange, but is particularly sensitive to infrared. (See fig. 11.)

104. Speed and contrast.—*a.* The relative speeds of negative emulsions vary over a wide range when used with daylight and even a greater range for artificial light. The emulsions at the extremes of this range are ordinarily used for special purposes. Color-blind emulsions of low speed are generally used in process photography because of their high potential contrast and resolving power. The fast emulsions ordinarily are of hyperpanchromatic sensitivity and are often used for exposures in artificial light because of their high sensitivity to red.

b. The inherent contrast of negative emulsions also varies over a wide range. The slower emulsions generally have higher contrast than the fast emulsions.

105. Choice of negative emulsions.—The choice of a negative emulsion is governed by the purpose for which it is to be used. Speed



1. Human eye sensitivity.
2. Color-blind emulsion.
3. Orthochromatic.
4. Panchromatic.
5. Infrared.

FIGURE 11.—Spectrograms—emulsion color sensitivity.

and color sensitivity are two primary factors to be considered in the choice of a negative emulsion. Emulsions may be divided into four speed classifications, as follows:

a. Color-blind emulsions are of the slowest negative material class and are especially suitable for copying. They have high resolving power, low graininess, high rate of development, and high potential contrast. A process emulsion is one made especially for the reproduction of line work in high contrast. Color-blind emulsions of a higher speed rating than a process emulsion are also widely used in copying when normal contrast is desirable and true color rendition unnecessary.

b. (1) In general photography when speed is not a factor, a film of moderate speed may be chosen. Moderate speed emulsions are known as commercial emulsions and may be of almost any spectral sensitivity. If color separation is desirable, an orthopanchromatic emulsion should be chosen unless the color separation is such that an orthochromatic emulsion will suffice. Commercial emulsions are also widely used in copying.

(2) The largest group of emulsions which may be included in a single class are those which are just above the speed of the commercial group. They are practically all of orthochromatic or panchromatic sensitivity. Their speeds cover a wide range from moderate to ultra-fast. Their contrast and development characteristics also cover a wide range, but the initial contrast of any emulsion of this class is considerably lower than that of any film of the commercial type. Films of this type have reasonably high speed, good exposure latitude, acceptable graininess, and satisfactory keeping qualities.

c. Ultra-fast emulsions are used when speed is the essential. They are usually manufactured only in orthochromatic or panchromatic sensitivity.

d. Infrared emulsions are made for the purpose of making photographs with the aid of infrared radiations. Aside from the value of infrared photography in medical diagnosis, criminology, biological and botanical research, and many other allied fields, it is invaluable to the aerial photographer as a means of procuring photographs at high altitudes or at great distance from the subject. Infrared radiations readily pass through suspended dust and water vapor in the atmosphere, thus permitting their use with an infrared sensitive emulsion under conditions both impracticable and impossible with other negative materials. An infrared emulsion is characteristically similar to a commercial color-blind emulsion with the exception of its sensitivity to infrared light.

106. Types.—The different types of negative materials are roll film, cut film, film pack, and plates.

a. Roll film is of many different kinds, sizes, and color sensitivities. Ordinary roll film is that made for amateur cameras and consists of a strip of film wound on a suitable spool with opaque backing paper. The base is thin for flexibility.

(1) Aerial film is a special type of roll film supplied in greater widths and lengths. There is no backing paper on aerial film because of the bulk, but there is an opaque leader on each end of the roll to protect it from light. The base is thicker than that of ordinary roll film because of the large negative size, and it is often especially prepared to have very low shrinkage.

(2) Motion-picture film is made in long narrow strips with perforations on the sides to allow accurate positioning of successive small portions of the film in the exposure aperture of the camera. There are two standard widths of motion-picture film, 35- and 16-millimeter. The 35-millimeter film is the professional width and is also used extensively for amateur photography with miniature cameras. The 16-millimeter film is used most in amateur movie photography.

b. Cut films and plates are most widely used in commercial photography. They are available in large sizes and are particularly well-suited for use with professional cameras. Since each negative is a separate piece of film, it can be exposed and developed individually. Emulsions are available in this form to conform to the large variety of applications in commercial photography.

c. Film packs have an advantage over cut films since they can be loaded into an adapter and the adapter inserted in the camera without the aid of a darkroom. There are generally a dozen sheets of film in a pack. When one has been exposed, it is pulled by a paper tab to the back of the pack and the next sheet is ready for exposure. These sheets can be removed from the pack individually if necessary. In order to obtain flexibility, the base is made thinner than that of cut film. Only the most widely used emulsions are available in pack form. (See fig. 12.)

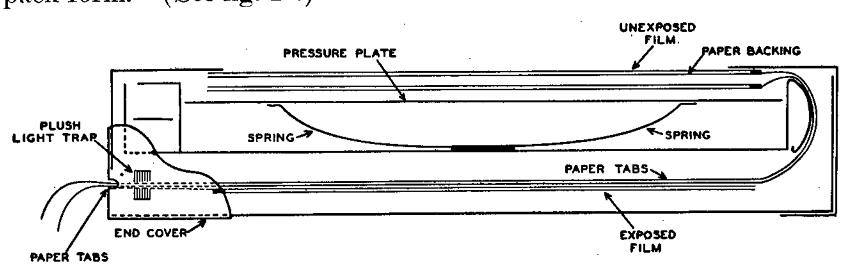


FIGURE 12.—Cross section of film pack.

107. Identification code.—Cut films of all emulsions are furnished with reference notches near one corner. This is to identify the emulsion surface during loading of the film. When the notches are in the upper right corner, the emulsion surface is toward the operator. These notches are also in the form of a code to identify the type of emulsion. Each film manufacturer has a particular code which does not overlap any other. Thus the film can be positively identified as to type of emulsion and emulsion surface while the operator is in total darkness. (See fig. 13.)

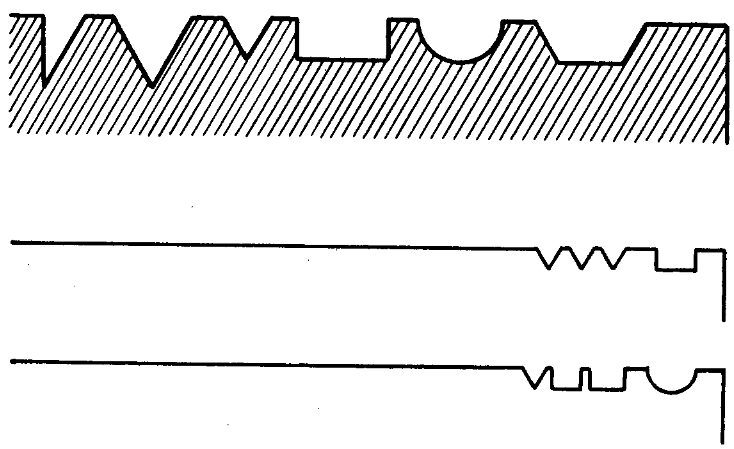


FIGURE 13.—Notching code for cut film.

SECTION V

POSITIVE MATERIALS

108. General.—Positive emulsions differ considerably. In general they have a much finer grain, are slower than negative emulsions, and have somewhat higher contrast. Positives are made on transparent or translucent bases to be viewed by transmitted light, either directly or by projection, or on opaque bases to be viewed by reflection.

109. Transparencies.—The principal positive materials viewed by transmitted light are motion-picture positives and lantern slide plates or films, both normally used for projection on a screen.

a. Motion-picture positive film.—This film is coated with a bromide emulsion. Its speed and color sensitivity compare favorably with a slow process color-blind emulsion of potentially high contrast. Correct exposure and contrast of an emulsion of these characteristics depend very markedly upon the degree of development. The graininess is much lower and the resolving power much higher than that of ordinary negative materials. Motion-picture positive film is used for motion-picture positives, lantern film slides, and to some extent for microcopying work.

b. Lantern slide plates (glass).—These plates have a bromide emulsion similar to that of positive film. They are available in several grades of contrast. As with negative bromide emulsions, a wide range of contrast can be had by proper manipulation of developer and developing conditions. To further the range of contrast, lantern slides are sometimes coated with a special chloro-bromide emulsion.

110. Paper prints.—Paper emulsions are of three types; bromide, chloride, and chloro-bromide. These emulsions are made especially thin in order to enhance the reflective ability of the finished print and as an aid to flexibility. They are of fine grain and high resolving power.

111. Speed.—Positive emulsions cover a very wide range of speed, the chlorides being the slower and the bromides much faster. The speed of chloro-bromide emulsions overlap these two divisions.

a. Chloride emulsions are generally made for the purpose of direct contact printing. A rapid chloride paper is also made for projection, but is slower than ordinary bromide papers.

b. Bromide emulsions are made for the purpose of optical or projection printing.

c. A chloro-bromide emulsion, due to its variance in speed characteristics, may be used for either contact or optical printing. The slower ones are suitable only for contact work while those of more bromide content are chiefly suitable for projection.

112. Paper contrast.—*a. Development.*—Owing to the thinness of the coating and fine grain, a paper emulsion develops rapidly. Contrast rapidly increases during the first period of development, but increases more slowly as the shadow density approaches its maximum. Bromide and chloride emulsions should be developed to a standard degree of development which will produce what may be termed normal or "full" development. This development will reproduce the contrast gradations of the negative in their truest relationship, providing an emulsion of the proper *inherent* contrast is used. Less development than normal will result in uneven contrasts and densities. More than normal development will result in a slight contrast and density increase but is generally impractical for the reason of its slight value and may cause serious harm by way of stains. Chloro-bromide emulsions are similar to film emulsions in their reactions to a developer. Developer modifications of ingredients, and time of development, as well as temperature variations may therefore be employed advantageously. Emulsions of this type are capable of producing satisfactory results over a wide range of negative contrasts and are of value in producing special effects such as a control of contrast (to the minimum or maximum) without an appreciable loss of general print quality.

b. Inherent contrast.—Since contrast is only slightly variable by development manipulation, paper emulsions are therefore manufactured with a wide range of inherent contrasts. This wide range of available contrasts increases the acceptable range of negative emulsion contrast. The potential contrast of an emulsion is usually expressed by a number or a descriptive word, the exact method of expression being dependent upon the manufacturer.

113. Paper bases.—*a.* Photographic papers are made in varying thicknesses or weights. The three most common are known as lightweight, single weight, and double weight. A lightweight paper may be rolled, bent, or folded without appreciable damage, although treatment of the finished print with a glycerin bath or similar softening agent is usually necessary if the print is to be folded. A single-weight paper is usually the type used for small pictures, including 8- by 10-inch. A double-weight paper is generally used for larger prints to facilitate their handling. It is especially desirable for rough paper surfaces.

b. Most papers are coated with *baryta* as a support for the sensitive emulsion. Papers of this nature cannot be folded satisfactorily without cracking. The baryta layer is therefore not used when the product is made with the expectation that its use may necessitate folding or sharp bending.

114. Surface texture.—After paper is surfaced with baryta, it is embossed, producing almost any desired surface effect when the emulsion is coated. Linen, tapestry, matte, semimatte, glossy, and smooth are a few common surface textures. These effects are aided somewhat by the paper texture. Surface texture is most often considered in selection of papers for particular types of photographs. Glossy or smooth surfaces are preferable for small prints or prints wherein maximum detail is desirable. Rough surfaces are generally preferred for enlargements. They have the faculty of suppressing excessive fine detail or concealing a lack thereof and also suppressing apparent graininess.

Section VI

SPECIAL EMULSIONS

115. Reversal.—*a.* A reversal emulsion is made for the purpose of producing a positive image with the same emulsion used as the negative. Upon the completion of development, such an emulsion contains two images, that of the exposed and developed silver in negative relationship to the subject, and that of the unexposed and therefore undeveloped silver. The exposed and developed silver image is eliminated by bleaching, and a second image exposed and developed to form a new image of reversed density values which truly represents the subject.

b. Since nearly all silver halide grains are utilized in this process, the exposure latitude of any emulsion used for reversal purposes is very limited. Emulsions made for the purpose are extremely thin so as to offset the possibility of too great a highlight density caused by the second exposure. Reversal emulsions are often used for colored photography.

116. X-ray.—Silver halide absorbs only a small portion of the incident radiations of X-rays. X-ray materials are therefore coated on both sides or are abnormally thick. Because of developing and fixing difficulties of a thick emulsion, the former is the more desirable. To increase the photographic action on the sensitized emulsion, it is customary to place the emulsion behind an intensifying screen coated with calcium tungstate which fluoresces under the action of X-rays. The greater part of the exposure is therefore due to visible fluorescent light from the intensifying screen.

Section VII

SAFELIGHTS

117. Use of safelights.—Safelights are used in processing photographic materials where it is necessary to view the emulsion during development or to furnish sufficient light for visibility in darkroom operations. Essentially, they are filters whose function is to transmit a maximum of visible light to which the emulsion is not sensitive or is only somewhat sensitive. Since color sensitivity varies with different emulsions, the light transmission properties of safelights must vary accordingly.

a. Noncolor sensitized (ordinary) emulsions of the slower speeds may be safely processed under any safelight not transmitting blue or violet radiations (series 00, 0, or 0A). Such safelights are usually yellow or yellow-green in color. The faster ordinary emulsions have an extended sensitivity and should be processed under a red light (series 1).

b. Orthochromatic emulsions should be processed under a deep red light (series 2) since their sensitivity range does not include red.

c. Orthopanchromatic emulsions and those panchromatic emulsions sensitized primarily to blue may be processed under a dark green safelight (series 3). Hyperpanchromatic and panchromatic emulsions of great speed should be handled in total darkness.

d. Infrared emulsions should be handled in total darkness or with the aid of an infrared safelight (series 7). This safelight, although "safe" for use with infrared material, can not be safely used with orthochromatic or panchromatic materials.

e. The results of printing, both contact and projection, are ordinarily judged in the darkroom so that proper safelights are necessary. Chloride papers can be safely processed under yellow light (series 00), but bromide papers should be handled under orange or greenish-yellow light (series 0 or 0A).

Chapter 5

OPTICS

Section I

PROPERTIES OF LIGHT

118. Definition.—Optics has been defined as the science treating of light, its genesis and propagation, the effects which it suffers and produces, and other phenomena closely associated with it. A textbook on the subject usually includes also the control of light by means of prisms, lenses, mirrors, and other media. In this manual, however, only so much of optics will be presented as will achieve such familiarization with the lenses used in photography as will guide the photographer in the selection of the most suitable type of lens for the kind of work in hand.

119. Theory of light.—The generally accepted theory of light is that it is propagated as a wave action or radiation. The speed of light is constant for all radiations in a given medium and is approximately 186,000 miles a second in air. If light enters a denser medium the wave is shortened, but the number of pulsations (waves per unit of time) remain constant. The waves per unit of time are known as the frequency of the vibration. Since the wave is shortened when light transverses a denser medium and the frequency of vibrations remains constant, the speed of the light is lessened. Sunlight is the simultaneous perception of many and varied waves or radiations which produce the sensation of white light. If a beam of sunlight is passed through a glass prism, the colors of some of its component rays are made visible. The most prominent of these are red, orange, yellow, green, blue, and violet, but there are also intermediate shades of colors between each of the six and it has been found that there are waves of colors beyond each end of this visible band or spectrum which cannot be seen with the eye. Those below the red end are known as the infrared rays, and those beyond the violet are called ultraviolet rays. The infrared rays are too long to be seen, and the ultraviolet rays are too short.

120. Characteristics of light.—Light is capable of being refracted, reflected, transmitted, or absorbed.

a. Refraction.—(1) When a ray of light passes obliquely from one medium into a medium of different density, its direction is changed. This characteristic enables a lens to form an image. A ray of light entering any medium perpendicularly to its surface is called a "normal ray." Its direction is unchanged. (See fig. 14.)

FIGURE 14.—Refraction of light.

(2) When white light enters a prism, the waves are refracted in different degrees dependent upon the length of the waves. The red rays are refracted the least and the violet rays the greatest. This phenomenon is called "dispersion." (See fig. 15.)

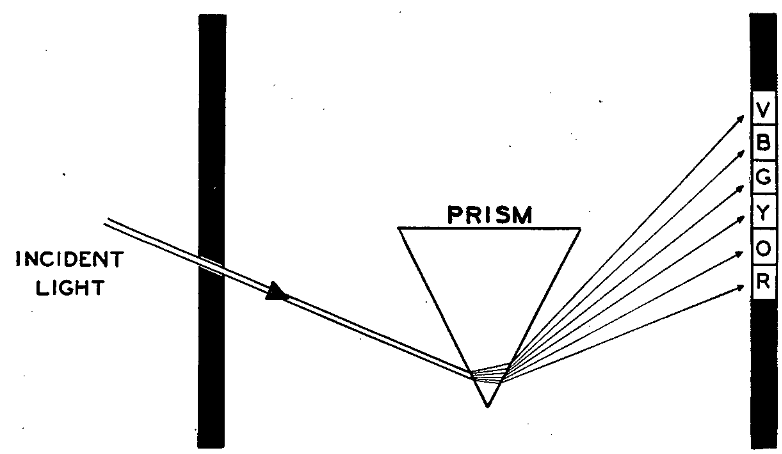


FIGURE 15.—Dispersion of light through a prism.

b. Reflection.—When light is diverted from a surface, the action is called "reflection." The reflected ray is in the same plane and at the same angle to the surface as the incident ray. (See fig. 16.)

c. Transmission.—Light passing through a medium is transmitted. If objects can be clearly distinguished when viewed through such a medium, the medium is transparent. When objects are not clearly distinguishable when viewed through a medium, it is translucent. When

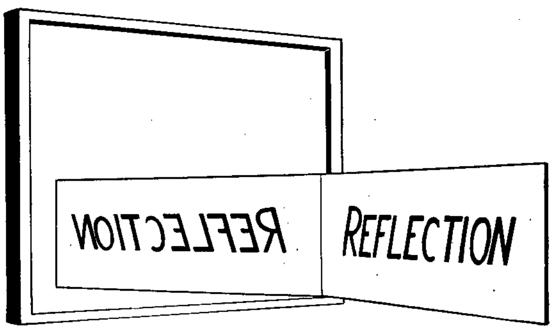


FIGURE 16.—Reflection of light.

light is transmitted through a translucent material the rays are scattered, producing the effect called "diffusion." (See fig. 17.)

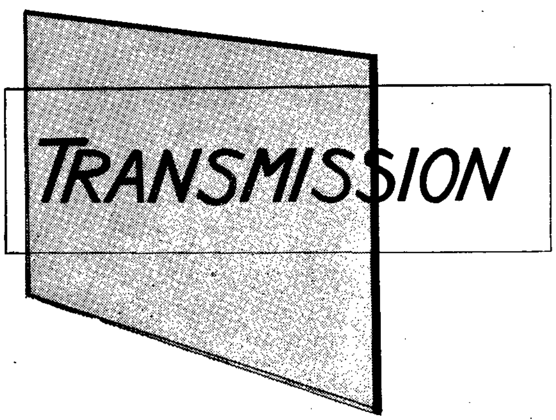


FIGURE 17.—Transmission of light.

d. Absorption.—Light which is incident upon a medium and is not reflected or transmitted is absorbed. An opaque substance is one which does not transmit light but which may or may not be capable of reflecting light.

SECTION II

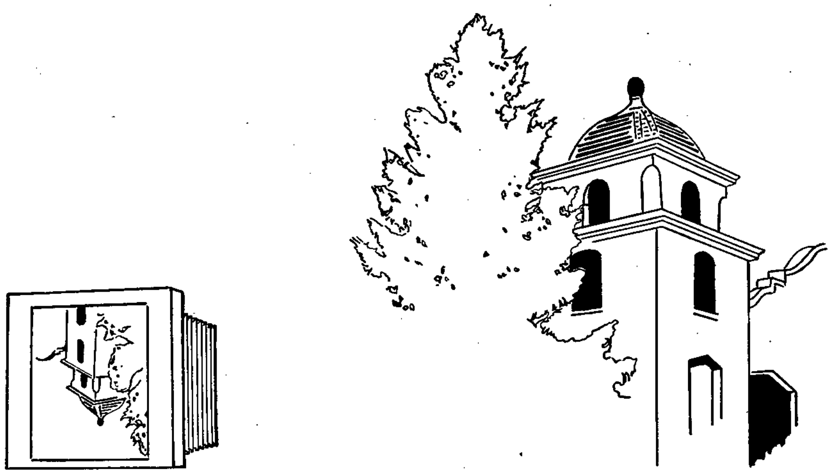
APPLICATION OF LIGHT

121. The lens.—*a. Description.*—A lens is a transparent medium having two opposite regular surfaces which forms an image by changing the direction of rays of light. Although lenses can be made of any refracting medium, they are usually composed of glass.

b. Function.—The function of a lens in photography is to project an image of an object. A lens must be designed to refract the light in such a manner that the rays from any one point of the object, irrespective of where they fall upon the lens, will meet, forming an image of the point. The extent to which a lens will refract a ray of light depends upon the curvature of the lens surfaces, the thickness of the lens, and the kind of glass of which it is made.

122. Formation of images.—*a.* Every point on an object sends out rays of light in all directions. These may either originate within the object or be reflected by it. It is the function of the lens to project these rays to a common plane in the form of an image. As the rays from a single point in the object pass through the lens, they are refracted and converge to a single corresponding point in the image. The point at which the rays from the object converge is called the "focus." Rays from every point on the object are similarly treated, resulting in a collection of points which forms an image in an inverted position. Image formation is illustrated in figure 18.

b. The plane on which a lens forms an image is known as a "focal plane" and the distance from this plane to the lens depends upon the distance of the lens from the subject and the focal length of the lens. Ordinarily a camera is provided with a mechanical means of adjustment for focusing; that is, moving the lens at different distances from the focal plane depending upon the distance the lens is from the object or subject to be photographed. As aerial cameras are ordinarily used at the lens infinity distance or farther from the subject, they are usually built without a focusing adjustment. Some types of



① Image of subject. ② Subject.

FIGURE 18.—Image formation.

hand-held cameras employing lenses of very short focal length do not have a focusing device and are known as "fixed focus."

123. Focal length of a lens.—*a.* When rays of light parallel to the optical axis of a lens are incident upon a positive lens surface, they are refracted by the lens and intersect on the opposite side of the lens at a point called the "focal point." The distance from this point to the optical center of the lens is the "focal length." Since a negative lens diverges rays of light, there would be no real intersection of the refracted rays. To find the focal point and focal length of a negative lens, the refracted rays are extended backward until they intersect. The intersection of these virtual lines is the focal point of the negative lens, and the focal length is the distance from it to the optical center of the lens (fig. 19).

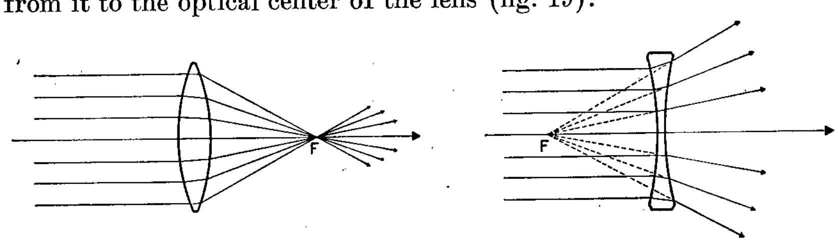


FIGURE 19.—Focal length of lens.

b. A focal length may be defined also as approximately the distance from the lens to the projected image when the lens is focused on an object at infinity distance for that lens.

c. There are three factors which determine the focal length of a lens; namely, the curvature of the lens surfaces, the kind of glass used in its construction, and the separation between the lens elements. The first two factors cannot be changed but the third factor is variable and may be used to change the equivalent focal length. Some lenses are so mounted that the front element can be moved, thereby changing the focal length. Cameras of this type have a fixed distance from the rear element to the focal plane. They are consequently focused on objects by moving the front element. This type of lens is also used in cinematography to produce special effects.

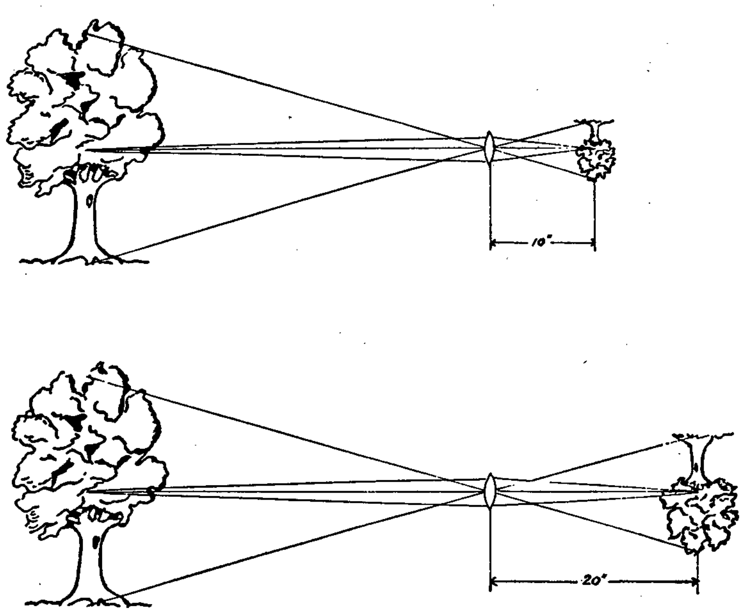


FIGURE 20.—Size of image in relation to focal length.

d. The size of the image is directly proportional to the focal length of the lens. To illustrate, suppose it is desired to photograph an object, such as a tree, and that the camera is placed at such a distance from the tree that with a lens of 10 inches in focal length a clearly defined image of the tree 1 inch in length is obtained on the focusing screen. Replacing the 10-inch lens with one having a focal length of 20 inches, a clearly defined image of the same tree would then be 2 inches or twice as long as the image given by the 10-inch lens if the position of the camera remains unchanged (fig. 20).

124. Use of terms.—In photographic optics, there are a number of technical terms so commonly used that all photographers should know them and in their work take advantage of the optical law involved. These common terms are—

a. Speed of a lens.
b. Circle of confusion.
c. Hyperfocal distance.
d. Depth of field.
e. Depth of focus.
f. Lens definition.
g. Angle of field.
h. Angle of view.
i. Conjugate distances.
j. Resolving power.
k. Aberrations.

125. Speed of a lens.—The speed of a lens is determined by two factors: the diameter of the effective aperture which, practically speaking, is the width or diameter of the lens, for obviously through a large aperture more light will pass than through a smaller one; by the bellows extension, which is the distance the light has to travel after passing through the aperture until it reaches the film.

a. f/ system.—This speed is usually expressed in terms of the ratio existing between the diameter of the effective aperture and the focal length, that is, focal length divided by diameter. This is the basis of what is known as the *f/* system used in marking diaphragm openings. This ration of *f/* value may be determined from the following formula:

$$f/=F\div D$$

in which *f/* represents the speed of the lens, *F* the focal length, and *D* the diameter of the aperture or opening. For example, if the diameter is 2 inches and the focal length 8 inches, the speed would be expressed under this system *f*/4. *The amount of exposure required at different lens apertures or openings varies directly as the square of the f/ value.* If the diaphragm is set at *f*/4, and the required exposure is 4 seconds, at *f*/8 the required exposure would not be twice as much, or 8 seconds, but 16 seconds. The formula for readily computing this is:

$$f/^2:f/_1^2::t:t_1$$

in which t represents exposure time required at original *f/* setting, t_1 the exposure time required at desired $f/_1$ setting, and $f/_1$ the new diaphragm setting required. If the diameter of the *f*/4 diaphragm setting is 2 inches on a lens having a focal length of 8 inches, then the diameter of diaphragm setting $f/8$ would be 1 inch. As shown in figure 21, a square with sides 1 inch in length has an area only one-fourth that of a square with 2-inch sides, so that four times more light would pass through an aperture 2 inches square than through one that is 1 inch square.

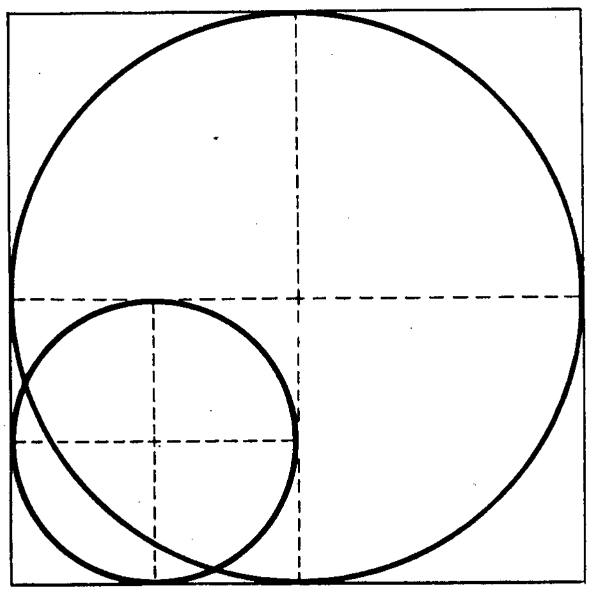


FIGURE 21.—Areas of diaphragm openings.

b. Effect of bellows extension on lens speed.—When the bellows of a camera are extended to any length greater than the optically fixed focal length of the lens for objects at infinity distance or beyond, the speed of the lens as indicated on the lens barrel or shutter is not the actual speed. Therefore, the speed as engraved on the barrel or elsewhere is the true speed only when the distance from the lens to the image plane is equal to one focal length. When this distance exceeds one focal length, the actual or effective speed is less than the indicated speed.

(1) *Inverse square law.*—The effective speed of a lens is diminished in proportion to the extension of the camera bellows beyond one focal length because light intensity reduces as the distance the light travels increases. The extent to which light intensity varies with respect to travel is expressed by the inverse square law which is as follows: The intensity of light varies inversely as the square of its distance from the source (fig. 22). The shaded area at point *A* represents the

sensitized material, which is a certain distance from the lens. When the film is moved to point B, which is twice the distance from the lens, the light is so spread out that it covers a surface four times the size of the film. Therefore, the intensity of the light on the film at this point is only one-fourth of what it is at point A. At point C, which is three times the distance, the intensity of the illumination is one-ninth. At point D, four times the distance, the intensity is only one-sixteenth.

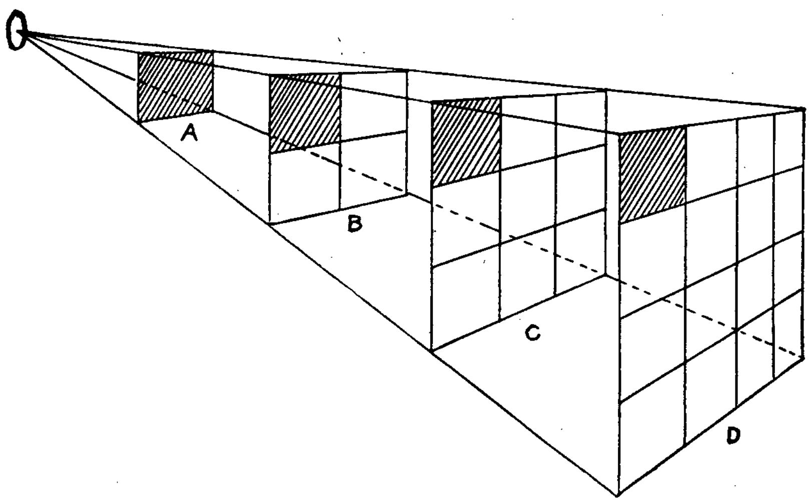


FIGURE 22.—Inverse square law.

(2) *Variance.*—Photographic exposures vary, not inversely, but directly as the square of the distance from the light source. For example, if the film is 12 inches from the lens and the correct exposure time is 2 seconds, the time necessary if the film is placed 24 inches from the lens will be 8 seconds. The solution is as follows: Original bellows extension squared is to the new bellows extension squared, as the original exposure is to the new exposure.

$$12^2 : 24^2 :: 2 \text{ seconds} : x \text{ seconds} = 8 \text{ seconds}$$

126. Circle of confusion.—The circle of confusion is the diameter of the circle to which the image of a point will spread at the focal plane. It is expressed as a numerical valuation and is determined by the manufacturer of the lens. A circle of confusion is obtainable only when the image of a point in the object space is out of focus. The only practical use made of the circle of confusion is in the computation of the hyperfocal distance and the depth of field. The diameter of the circle is an arbitrary constant, the magnitude of which is dependent upon the enlargement and viewing distance of the final print. For critical definition the circle of confusion in a print to be viewed at the distance for normal perspective should not exceed $\frac{1}{2000}$ of the focal length of the camera lens.

127. Hyperfocal distance.—The distance from the lens to the nearest plane in sharp focus, when the lens is focused at infinity distance, is called the hyperfocal distance (fig. 23). From the formula which follows, it will be seen that the hyperfocal distance (H. F. D.) increases as the focal length increases, and decreases as a smaller diaphragm setting is used. The H. F. D. of any lens is found by multiplying the focal length squared by the reciprocal of the circle of confusion and dividing by the $f/$ value. This result divided by 12 will be the H. F. D. in feet.

$$(F^2 \times 1/c) \div (f/ \times 12) \text{ or } \frac{F^2 \times 1/c}{f/ \times 12} = \text{H. F. D.}$$

c represents circle of confusion, F equals the focal length, and $f/$ is the diaphragm setting. When a lense is focused at infinity or at the hyperfocal distance it will be found that acceptable focus extends towards the lens to approximately one-half the distance from the lens to the hyperfocal distance. Thus the acceptable depth of field is greater than the distance from the hyperfocal distance to infinity.

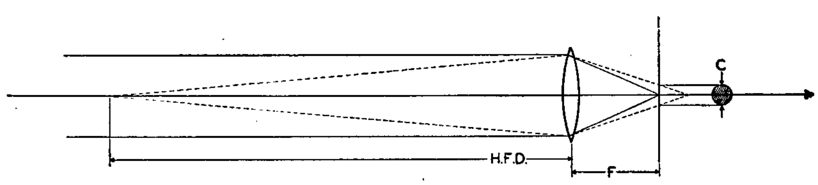


FIGURE 23.—Hyperfocal distance.

128. Depth of field.—*a*. The depth of field of a lens is the distance from the nearest point of the subject in acceptable focus to the farthest point of the subject in acceptable focus. Depth of field decreases either as the size of the aperture or as the focal length increases. Depth of field increases as the object distance increases. All lenses having the same speed and focal length have the same depth of field. Variation of the factors governing depth of field may be stated as follows:

(1) With a given focal length and object distance, the smaller the diaphragm opening, the greater the depth.

(2) At a given object distance and diaphragm opening, the shorter the focal length, the greater the depth.

(3) With a given focal length and diaphragm opening, the greater the object distance up to infinity, the greater the depth.

b. A formula for determining the depth of field of any lens with the subject at the given distance is as follows:

Let $d=$ lens to subject distance

H. F. D. $=$ hyperfocal distance

$Dn=$ distance to nearest plane of focus

$Df=$ distance to farthest plane of focus

$$Dn=\frac{\text{H. F. D.}\times d}{\text{H. F. D.}+d}$$

$$Df=\frac{\text{H. F. D.}\times d}{\text{H. F. D.}-d}$$

The distance from the near plane of focus to the far plane of focus is the depth of field.

$$Df-Dn=\text{depth of field}$$

c. The portion of the subject which will appear in sharpest focus in the image lies in a plane which is approximately two-fifths of the distance into the depth of field. For this reason it is desirable to adjust the camera with the lens set at its greatest aperture so that the plane of best focus will be two-fifths of the distance into the desired depth of field; then decrease the aperture until the desired depth of field is obtained.

129. Depth of focus.—Depth of focus is the allowable distance on either side of the focal plane in which acceptable focus is rendered. In practice, depth of focus is used mostly in connection with focusing screens and determines the extent or latitude of allowable movement of the focusing screen within which good focus is rendered.

130. Lens definition.—Definition is the accuracy with which a lens will render an image. If it is impossible to secure a wire-sharp image with a particular lens, the lens has poor definition.

131. Angle of field.—*a*. The angle of field or angular field of a lens is a property of the lens and may be defined as the angle subtended by lines that pass through the center of the lens and locate the diameter of the maximum image area within the specified definition of the lens. (See fig. 24.) It is the function of the particular type of lens to form properly an image within the desired angle. For example, wide angle lenses are made to "cover" wide angles and telephoto lenses a relatively narrow angle.

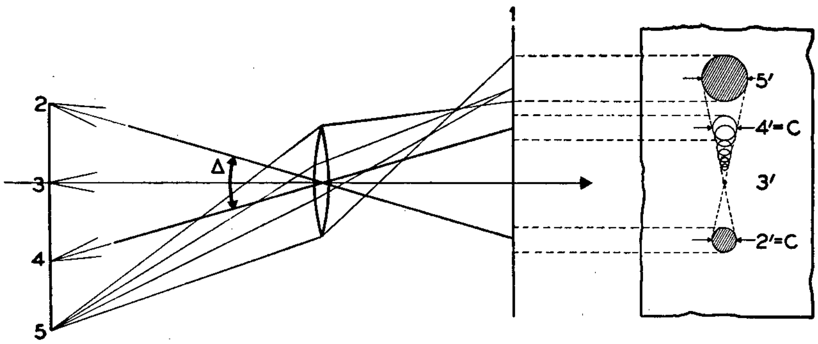


FIGURE 24.—Angle of field of a lens.

b. The covering power of a lens is the area of the focal plane lying within the circle determined by the angle of field. (See fig. 25.)

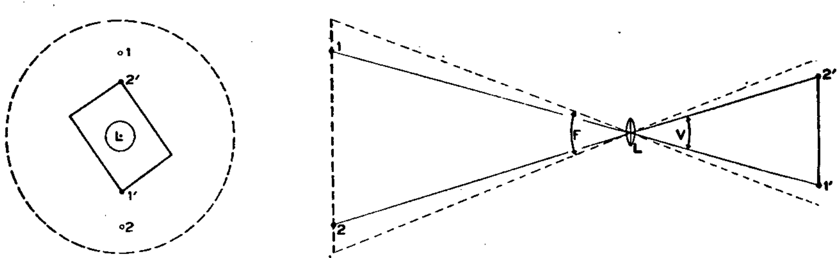


FIGURE 25.—Covering power of lens.

132. Angle of view.—The angle of view is considered as the angle subtended by lines which pass through the lens to diametrically opposite corners of the plate or film used. This angle of view of the camera varies with the photographed image and the bellows extension. (See fig. 26.)

133. Conjugate distances.—For every distance that an object may occupy with respect to a lens there is a corresponding distance for the image. The object and image are conjugate (coupled together) to each other relative to the lens, and the corresponding distances from object and image to lens are called "conjugate distances." Any point of an image with its corresponding point of the object may be called "conjugate foci." (See fig. 27.)

134. Resolving power.—The resolving power of a lens is the optical ability of a lens to record minute lines or points clearly, distinctly, and separately, and is a function of the effective diameter of the lens. The smaller the effective diameter of the lens, the greater the resolving power.

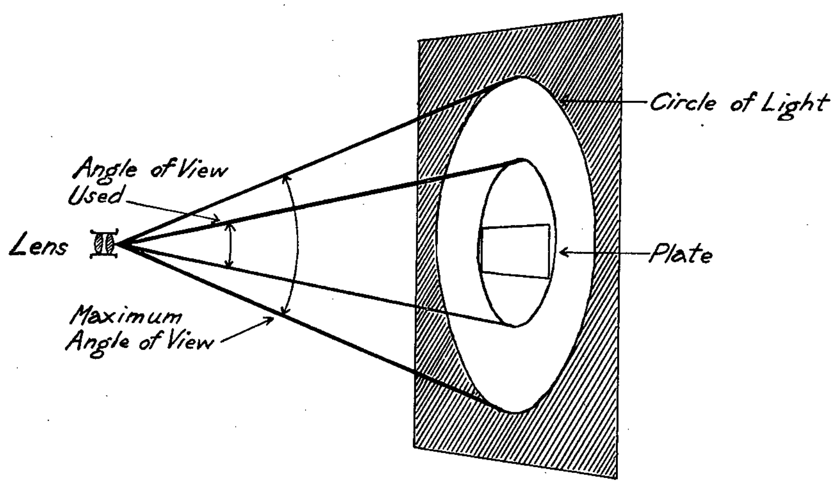


FIGURE 26.—Angle of view.

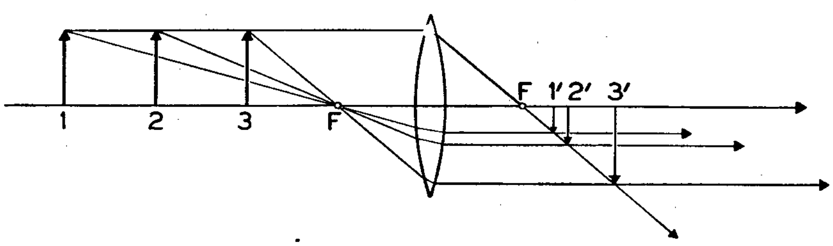


FIGURE 27.—Conjugate distances.

135. Lens aberrations.—An aberration is the effect of an optical error and results from the deviation of light from its desired path through the lens to the image. There are seven aberrations which are common to lenses and are generally corrected in high grade photographic lenses. These aberrations are chromatic, curvature of field, spherical, coma, astigmatism, curvilinear distortion, and optical flare. Most high-grade photographic lenses are called "anastigmats" and are corrected for the first six of the named aberrations. Optical flare is present in all lenses since it is caused by reflections from the surfaces of the lens elements, but is somewhat reduced by the use of a suitable lens hood. Some of the latest high-grade photographic lenses are chemically treated on the surfaces exposed to air. This treatment is a recent discovery which greatly reduces optical flare within the lens. Although an anastigmat is corrected for chromatic aberration, the correction is not perfect since red rays focus a little beyond the focal plane. An apochromatic lens is one which is further corrected for chromatic aberration and focuses rays of all visible colors on very nearly the same plane. This lens is also corrected for the other common aberrations with the exception of flare. In a lens which is to be used for photographic purposes, these seven major defects must be reduced to the lowest possible values in lens design by proper selection of glasses, lens thicknesses, curvatures of various surfaces, and spacing between the elements.

136. Cleaning a lens.—A lens should be cleaned only when necessary. Lenses in storage in warm humid climates should be cleaned at least every 30 days to prevent the formation of fungus growth. In cleaning a lens, all loose dust should be removed by brushing with a soft camel's-hair brush. A vacuum system may be used, provided care is exercised to avoid striking the lens. Breathing on a lens and polishing it with a clean soft cloth or paper lens tissue will assist in the removal of the oily film resulting from finger prints, etc. A solvent will not be used unless specified by a Technical Order and designated as such for the purpose.

137. Care of a lens.—A lens should not be subjected to direct sunlight, excessive heat, moisture, injurious acid fumes, nor to the possibility of any physical damage. Prolonged exposure to direct sunlight, heat, or moisture may cause the lens elements to separate and allow air to enter between them. This will cause an adverse refracting of the rays of light, resulting in an inferior image projection. Lenses should be stored in a dry place of moderate temperature, in a suitable container, and preferably capped.

CHAPTER 6

FILTERS

SECTION I

GENERAL

138. Definition.—A filter is a medium used to regulate the intensity or color of light.

139. Composition.—*a.* Some filters are made of dyed gelatin which is accurately compounded and the color standardized by comparison with a permanent standard. Gelatin or "wafer" filters may be used as they are or they may be cemented between glass. Some gelatin filters, cemented or not, are susceptible to fading at high temperatures. If uncemented, extreme care should be exercised in handling, as fingerprints and dirt will lower the efficiency of the filter. The chief advantages of gelatin filters are:

(1) They are available in a wide range of color or transmissions.

(2) They are easily adaptable under various conditions: they can be cut to any shape; they can be used in front of the lens, behind, or between the lens elements; or if necessary, they can be used in front of the light source in any size because of the low expense in comparison to cemented filters.

(3) In changing from one filter to another, there is no appreciable change in focus of the image. Focusing may be accomplished with or without the filter because gelatin filters do not shift the plane of the image.

b. Filters cemented between glass are of two grades, *A* and *B*, the letter denoting the optical quality of the glass.

(1) The best cemented filters are made with *A* glass which is ground and polished optically flat with both surfaces parallel. Filters of this type can be used for the most exacting requirements in any type of photographic work.

(2) *B* glass filters are of good quality glass and are suitable for amateur and commercial work. The surfaces of the glass are plane parallel but are not ground optically flat, and are not recommended for use with lenses having focal length greater than 10 inches, especially if large apertures are used with the lens.

c. Colored glass filters are the most permanent in respect to color transmission but are neither available in such a wide variety as are dyed gelatin nor are they as easy to reproduce as to standardization of transmission. The color of these glass filters is determined by metallic salts which are added to the glass when it is made. Glass filters of this type are practically unaffected by temperature. They are made of *A* glass quality and therefore of high optical excellence.

d. Any filters containing glass will move the plane of focus back slightly if they are placed in front of the lens. In many cases, such as landscape photography, this alteration is not important but when sharp images are required, it is necessary to focus with the filter in place.

e. Quite often a filter does not transmit enough light for accurate focusing. If a cemented filter is to be used, "dummy" filters are placed in the filter position during focusing and replaced by the real filter for the photograph. The refraction of light and consequent "moving back" of the image plane is compensated for by the use of the dummy. A dummy consists of plain glass with no selective absorption but nevertheless alters the image rays in a camera.

140. Purpose.—The purpose of a filter is to aid the photographic emulsion by the proper modification of light. The effect desired in using a filter is orthochromatic rendition, exaggeration or elimination of specified wave lengths, or exposure modification.

141. Action.—A filter produces its effect by absorption but it also transmits light (fig. 28). A wave of light freely transmitted by a filter will photograph as gray or white provided the emulsion is sensitive to that wave length. If a wave is more or less fully absorbed, it will photograph as dark or black. The greatest possible contrast in the use of filters is when photographing two colors, one of which is freely transmitted and the other fully absorbed. A filter may only partially absorb a color producing what is known as "retardation." The color so retarded will then photograph as a shade of gray, the density of which will be dependent upon the absorption property of the filter to the particular color. A filter may also have the property of absorbing light without modifying a particular portion.

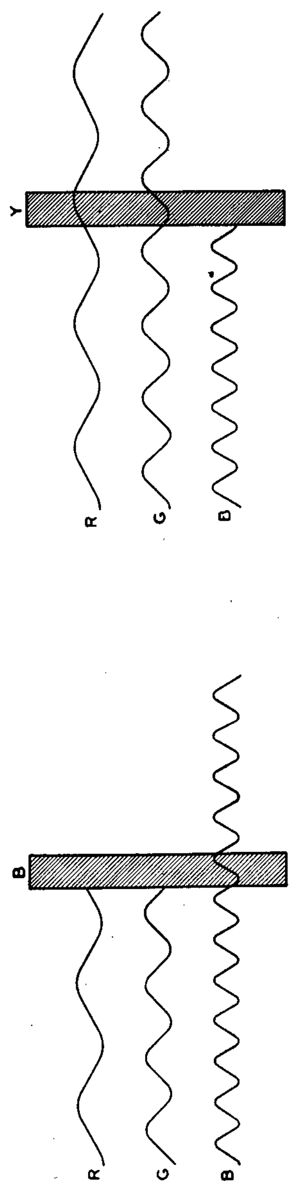


FIGURE 28.—Filter action.

142. Factors.—The employment of a filter results in the absorption of light to which the photographic emulsion is sensitive. The effective illumination is reduced, thereby necessitating an increased exposure. The number of times the exposure must be increased when using the filter as compared with the exposure necessary without the filter is known as the "filter factor." The filter factor depends on the absorption properties of the filter, the color sensitivity of the photographic emulsion, and the quality of the light source.

143. Care.—*a.* Gelatin filters should be kept in suitable envelopes when not in use and always stored in a clean dry place of moderate temperature, as dampness will cause the gelatin to wrinkle or curl. The bare fingers or hands should never be allowed to come in contact with the surface as grease and moisture from the fingers will cause spots and spoil the filter. It is practically impossible to clean a gelatin filter satisfactorily.

b. If a gelatin filter is to be cut for a particular purpose, it should be placed between two sheets of clean paper to avoid touching either surface with the fingers.

c. Cemented filters, when not in use, should be kept in suitable containers. They should not be subjected to excessive light, heat, moisture, or to the possibility of any physical damage. Some gelatin filters will fade upon prolonged exposure to high temperature or bright light, the effect of which will change the color absorbing power. Heat or moisture may cause a separation of the glass elements from the gelatin and consequent deterioration of the filtering properties.

d. Glass filters should be cleaned in a manner similar to that used in the case of lenses. They should never be allowed to become scratched or badly marked with fingerprints. Grease and dirt are best removed by breathing on a filter and then polishing it with a piece of soft, clean linen or lens tissue paper. If necessary, a glass filter may be cleaned by dampening some fine tissue with a weak solution of alcohol and water and applying it to the surface gently. Care must be taken that this solution does not come into contact with the edge of the filter as the material with which the filter is cemented will loosen and allow air to enter between the glass elements. Any gritty material should be removed from the surface by gentle use of a camel's-hair brush.

Section II

NATURE OF COLOR

144. Primary colors.—*a.* The range of wave lengths included in white light extends approximately from 400 to 700 millimicrons. A millimicron is a millionth of a millimeter and is the common unit in measurement of wave length. This is the normal extent of vision and may be equally divided into three regions, 400 to 500, 500 to 600, and 600 to 700. If a filter transmitted the first group of wave lengths, its color would primarily be blue. A filter passing wave lengths between 500 and 600 will be green, and a filter passing the last division of wave lengths will be red. From this division of the spectrum, it is evident that white light can be divided into three primary colors, red, green, and blue. (See fig. 29.)

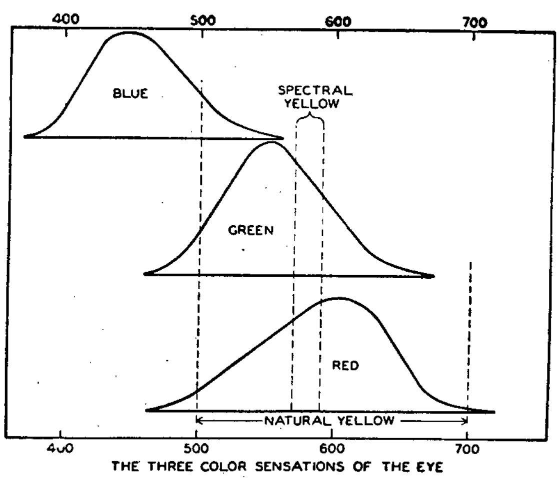


FIGURE 29.—Primary colors.

b. A filter is considered as red because it does not transmit blue and green. Therefore, blue and green will be subtracted from white light entering a primary red filter. A filter which absorbs red and green light appears blue and one which absorbs blue and red would appear green. When any one filter of a primary color is used, the other two primaries appear dark and the transmitted color appears light.

145. Secondary or complementary colors.—A secondary color is a mixture of two primary colors. A filter of a secondary color will transmit two primary colors and absorb the third. For example, yellow is a secondary color. A yellow filter will absorb blue light but will transmit green and red. Another secondary color, blue-green, includes the blue and green regions of the spectrum. A blue-green filter transmits the primaries, blue and green, but completely absorbs red. The third secondary color is a blend of blue and red, and absorbs the band of green in the middle of the spectrum. This blend of blue and red is known as magenta. The secondary colors are also called complementary. Yellow absorbs blue so it is complementary to blue. Blue-green absorbs red and is complementary to it. Likewise, magenta absorbs green so it is complementary to green. Each of these secondary colors has a definite band of absorption in the spectrum (fig. 30). The absolute degree of absorption of a color depends upon the saturation or color concentration. For example, a saturated yellow will not pass blue, but a less concentrated yellow will transmit some blue.

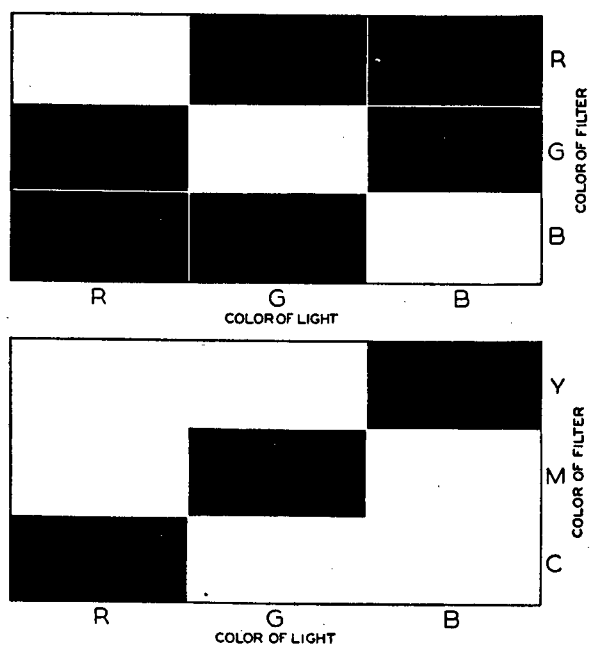


FIGURE 30.—Color absorption bands in spectrum.

SECTION III

APPLICATION

146. Colored objects.—Color is the visual interpretation of the various waves of visible light. It is caused by the absence of one or more radiations which are the components of white light.

a. The color of an object is conditioned by the absorption properties of the object itself. The object will reflect all light rays incident upon it which are not absorbed or transmitted. The true color of an object is the color reflected when the object is illuminated with pure sunlight. Any alteration in the quality of the viewing light will cause a change, not in the absorption ability of the object but in the quality of the light reflected. A light ray which is not present in the illuminant cannot be reflected. This fact will cause a change in the color which is reflected. For example, if red is viewed under a red light, it will appear light. If viewed under blue or green light, it appears dark or black because the color of the viewing light is absorbed by the object.

b. Visual sensitivity to color varies with the particular color. If a series of colored objects reflecting the same amounts of light are compared under diffuse daylight illumination, the yellow object will appear the most brilliant; green and orange will be less brilliant, but more so than red and blue.

147. Photographic reproduction of color.—The result produced when photographic emulsions are exposed to a series of colors receiving common illumination varies with the color sensitivity of the emulsion. The greater the sensitivity of the emulsion to a particular color, the greater the density of the negative and the lighter the shade of gray in which the color will be reproduced in the print. The result obtained is also dependent upon the quality of the light source. For example, blue will photograph darker with artificial illumination than when daylight is used because of the deficiency of blue in artificial light. The response of any photographic material to the relative brightness in which colors are rendered with the material and light source may be altered by the application of a filter possessing selective absorption.

148. Orthochromatic rendition.—The reproduction of color in its true aspect is called "orthochromatic rendition." In photography, other than color photography, the rendition of color as color is impossible because color is recorded only in varying shades of gray. Therefore, when speaking of orthochromatic rendition in the ordinary photographic sense it is meant that the color brightnesses will be in their relative shades of gray.

a. In most outdoor photography and in the copying of colored subjects other than line drawings, orthochromatic rendition is the aim sought. The filter used is termed an "orthochromatic filter." A filter of this nature retards only those rays which are unusually actinic. Since with most emulsions the sensitivity is greatest among the shorter rays of the visible spectrum, the absorptive property of an orthochromatic filter is principally to blue and violet. Perhaps the simplest and most outstanding example of using an orthochromatic filter out of doors is photographing a scene with a blue sky. The blue sky normally will photograph light. To photograph the sky darker, filtering is necessary. The greater the corrective property of the filter, the greater the amount of blue in the sky will be absorbed and consequently in the print the sky will appear darker. The orthochromatic filter usually employed for this purpose is yellow.

b. Many panchromatic emulsions are highly sensitive to red. Since red passes through yellow, the inherent sensitivity of the film to red will cause red to photograph too light in comparison with other colors. This emulsion sensitivity necessitates the use of an orthochromatic filter of some color other than yellow. In using these emulsions, the red or long wavelengths must be retarded as well as the blue or short wavelengths. Green filters are manufactured expressly for the purpose and are of such properties that red and blue are retarded to the extent of permitting only enough exposure to reproduce them satisfactorily in their relative densities.

c. In aerial photography, the primary purpose of a filter is haze elimination except when photographing for a special purpose such as camouflage detection. In the case of haze elimination, the desired result is orthochromatic rendition and clarity of detail (fig. 31). The actinic property of haze is particularly troublesome in that its action is so fast that the creation of the image formed by the light rays of objects cannot properly be recorded on the emulsion. Haze may be defined as the effect produced by rays of light emitted from tiny dust particles and moisture suspended in the atmosphere, such moisture and dust scattering the light rays. This scattering may be great enough to obscure visibility. It occurs through the entire spectrum, but is more pronounced among the shorter visible rays and the invisible ultraviolet. This fact and the fact that these waves are more actinic than others produce a photographic exposure obscuring the possibility of individual color or detail separation. A foggy effect with an inferior image recording is the result. A filter which will absorb the shorter waves (more actinic) eliminates this effect by preventing these waves from reaching the sensitized material. The particular filter used depends upon the amount of haze

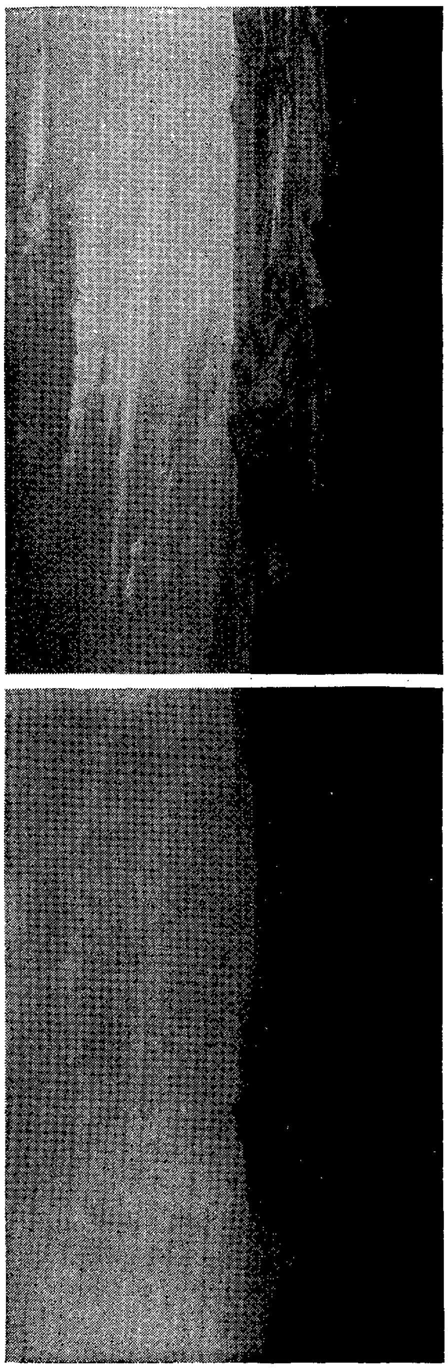


FIGURE 31.—Haze elimination by use of a filter.

present. It is therefore a process of subtraction or absorption of light rays.

149. Color exaggeration and elimination.—Filters used to exaggerate or eliminate a color or colors are generally referred to as contrast filters. They are chiefly used in the reproduction of colored line drawings. If it is desired that a colored line be eliminated from a drawing and the line is on a white ground, a filter which will freely pass the color should be used. The filter should either match the color of the line or be of a darker shade. If the colored line is on a black ground, a filter which absorbs the color should be used. It may be necessary to intensify a color as in the case of a blue signature. Without a filter, the blue would photograph too light to the possible extent of losing its legibility. A red or a green filter absorbs blue and therefore one or the other may be used. The usual procedure is to use the red because reproduction is generally done with artificial light which emits a high percentage of red. The result will be a dense black reproduction on a white ground.

a. To render a color lighter than it would appear with orthochromatic reproduction, a filter which selectively transmits light of the same color must be used; while to render a color darker, it must be photographed with the aid of a filter which absorbs light of that color.

b. By the use of contrast filters, any color in a subject may be emphasized or obliterated at will. Colored stains may be eliminated from prints, negatives, or lantern slides in reproduction by using a filter the color of the stain. Filters of the proper color may be selected by looking at the stain through the filters available. The selected filter should be one which will entirely, or as nearly as possible, eliminate the stain.

150. Exposure modification.—*a. Neutral density filter.*—An exposure modifying filter is one which regulates the intensity of light transmitted. A neutral density filter merely reduces the amount of light thereby making possible a greater exposure time or its equivalent. It cannot be classed as a color filter inasmuch as a modification of color is not possible.

b. Polarizing filters.—(1) The purpose of a polarizing filter is to reduce, not the general amount of illumination emitted from a subject, but particular reflections from the subject which are so bright they produce an excessive highlight exposure.

(2) When light falls upon a subject, the light reflected has two components known as specular and diffuse. The specular component produces what is known as gloss. It enables one to see the image

of the light source more or less distinctly, as when looking at a glossy surface. A matte surface reflects almost entirely the diffuse component. The diffuse component is reflected in all directions, hence does not give rise to an appearance of glossiness nor will it reflect an image of the light source. Because of this, only those surfaces which reflect specular light can be used as mirrors. A body viewed from one position may reflect a very diffused light but when viewed from other angles may exhibit a very high percentage of specular reflection. Specular reflection may be so great that proper image registration of the reflecting body is impossible. A polarizing filter is a device which is used primarily to absorb specular reflections. By adjusting the filter the percentage of this absorption can be controlled. About 50 percent of the diffuse component is absorbed at all positions of the polarizing filter. At a certain position all of the specular component is transmitted while at all other positions some of it is absorbed. At still another position all the specular light is more or less completely absorbed, depending upon the efficiency of the filter and the nature of the specular light. If all specular reflections are absorbed harsh contrasting reflections are eliminated. If the filter is so adjusted that all of the specular light is passed, its apparent presence is intensified. This is because the diffuse component remains approximately 50 percent absorbed. The image contrast will therefore be increased. Although subjects may be made to appear unnaturally glossy (lighting contrast increased) by the use of a polarizing filter, this change in contrast is not nearly so pronounced as it may be in the opposite direction.

151. Special filters.—The filters previously discussed are for the purpose of absorption or transmission of visible light. Quite often it is desired to eliminate or make use of those light rays which are not visible to the eye but which may be exceedingly actinic to a photographic emulsion. These are invisible because of their lengths, but often for the same reason, they may prove exceedingly useful or harmful in photography.

a. Infrared waves have the property of haze penetration to a much greater extent than the long waves of visible light. Therefore, infrared photography is utilized most often where it is desired to eliminate haze and secure sharp definition and contrast on distant objects. Infrared filters, in general, will transmit only the extremely long visible light waves and the infrared waves so that in use photographic exposures will be only to those waves. Photographic emulsions manufactured for this purpose are particularly sensitized to the infrared region but are also sensitive to blue, violet, and ultraviolet. Infrared filters will absorb the short wave lengths of light.

b. Ultraviolet light is invisible but often degrades blue exposure because of its extreme actinic properties which affect all photographic emulsions. For this reason, it is often necessary to absorb ultraviolet light to obtain true color rendition. Plain glass partially absorbs ultraviolet light but when complete absorption is the goal, a special filter is used. A filter of this type is visually colorless but actually is imbued with some chemical which has the property of complete absorption of ultraviolet light. If it is desired to utilize ultraviolet light, a filter is employed which will absorb most of the visible light but will transmit blue, violet, and ultraviolet. The short wave lengths are often useful in producing images of high resolving power.

CHAPTER 7

SENSITOMETRY

SECTION I

GENERAL

152. Definition.—Sensitometry is the quantitive measurement of the response of photographic emulsions to light.

153. Scope.—Since in the developing out processes the effect of exposure is apparent only after development, quantitive measurements of sensitivity are also measurements of the development effects. Sensitometric investigations involve the means of determining and expressing quantitively—

a. Speed or emulsion sensitivity.

b. Degree of development under various conditions of development.

c. Measurement and expression of contrast and maximum available contrast under known conditions of development.

154. Purpose.—Sensitometry provides a method whereby the effect of exposure and development on a photographic emulsion may be studied systematically. In this way it is possible to select and control these factors so that the desired final photographic result may be obtained.

SECTION II

SENSITOMETERS

155. Photographic exposure.—Measurements of the response of an emulsion to light are based fundamentally on the density produced under given conditions of development by a known exposure. Exposure is measured in terms of the illumination multiplied by the time during which the illumination acts. From this statement the fundamental formula, $E=IT$, is evident, in which E is total exposure, I is illumination and T is exposure time.

156. Sensitometric exposure.—*a. Light source.*—For consistent results, a standard light source is selected which closely approaches the type of illumination under which photographs are normally made. Incandescent tungsten light sources are generally used because they are easily controlled. To approximate daylight, a filter is used between the source of light and the emulsion in making the sensitometric exposure. The filter selected has a bluish hue because incandescent tungsten light predominates in the longer wavelengths which must be subdued. For highest precision, a liquid filter is most satisfactory, but practically, a gelatin filter of the proper transmission will suffice. The light source is operated at a constant voltage and amperage to maintain constant intensity and spectral distribution.

b. Sensitometers.—A sensitometer is an instrument by which a series of progressive exposures is obtained on a photographic emulsion. Since exposure is defined as the product of intensity and time, one of these two factors is kept constant while the other varies. The exposures are made in a series of steps which are evident after development as increasing densities (fig. 32). Sensitometers are of two general types, the time scale and the intensity scale.

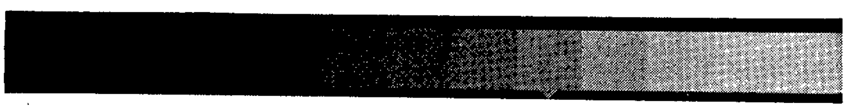


FIGURE 32.—Sensitometric strip.

(1) If time is the variable factor of the exposure, the sensitometer is of the time scale type. A common method of obtaining step exposures on a time scale is to introduce a revolving cylinder in front of the film position. This cylinder has on its surface a series of open slits whose lengths vary in accordance with the exposure times desired (fig. 33). Usually the lengths of the slits increase logarithmically by consecutive powers, or roots, of 2. The most common time factor is the square root of 2; thus each step receives 1.414 times the exposure of the preceding step. Light is directed from the source toward a mirror within the cylinder and is reflected onto the film, thus causing the exposure.

(2) An intensity scale sensitometer utilizes a screen which is placed in front of the emulsion. This screen is of increasing absorbing power

from one end to the other, and may be either of two types; an optical wedge in which the light absorption is continuous due to gradient density, or a step wedge in which the increase is discontinuous in steps of geometric proportion with a power, or root, of 2 factors (fig. 34). This screen thus varies the intensity of light incident upon the emulsion while the exposure time remains constant.

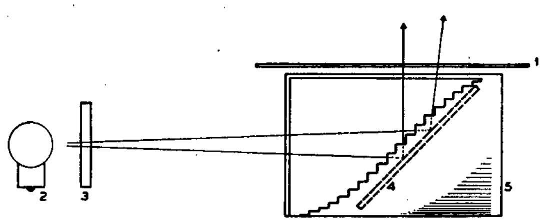


FIGURE 33.—Time scale sensitometer.

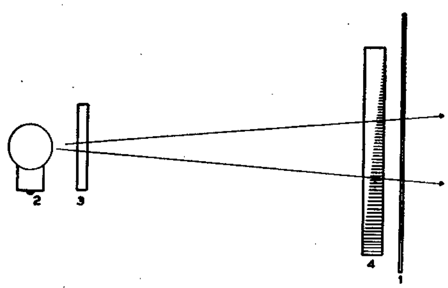


FIGURE 34.—Intensity scale sensitometer.

SECTION III

DEVELOPMENT

157. General.—The effect of exposure is apparent only after development, therefore the conditions of development must be standardized to secure accurate and reproducible results. In establishing standards for developers and development conditions, consideration must be given to the purpose for which the sensitometric work is being done. Since the characteristics of an emulsion can be considerably modified by the constituents of a developer, it becomes evident that if information is to be obtained for practical purposes, the standards adopted must be consistent with those of practical photography.

158. Conditions.—*a*. The technique of development employed in sensitometry is similar to that required in all photography. It differs in that more attention must be paid to such important factors as uniformity of development, temperature of development, agitation of developing solutions, and prevention of marks, abrasions, streaks, or stains.

b. Since the sensitometric procedures should be consistent with photographic practice and should also be reproducible, it is necessary to maintain normal conditions of development. Constant and vigorous agitation of the developer is essential to uniform and reproducible development. Solutions must be accurately made for consistent results. Temperatures of solutions must be kept constant and conform with those of normal working conditions.

159. Sensitometric strips.—To measure accurately the sensitivity of an emulsion, it is necessary to expose several strips of film in the sensitometer. These strips are then developed under specified and controlled conditions for different lengths of time. The developing times vary according to the emulsion and the developer, but generally the range of development time includes under development, normal development, and over development. The difference in development time will produce a difference in contrast. When development has progressed to a certain stage, dependent upon the emulsion, the developer, and other factors, contrast no longer increases with additional development time. When this point is reached, maximum available contrast has been achieved for the emulsion in the developer being used.

SECTION IV

DENSITY DETERMINATIONS

160. Density.—In development the exposed silver halide crystals are changed into grains of metallic silver. The degree of concentration and the magnitude of the silver deposit in the emulsion is expressed as "density." If a great many particles of silver are present, and do not allow much light to pass through the portion of the emulsion containing them, this portion will be very *dense*. Density, then, may be expressed in terms of the amount of light transmitted, or in the case of photographs on paper, the amount reflected.

a. A photograph of a subject contains highlights and shadows similar to those of the subject. In the negative, the highlights are represented by the heavy deposits of silver or the greater densities. The shadows, which represent the areas of least exposure, are the low densities or small silver deposits. These differences in density are apparent visually and may be expressed as low or high densities. Halftones are the intermediate densities between highlights and shadows.

b. In sensitometry, density is expressed as a definite valuation; therefore mere visual inspection of a silver deposit in a photographic image is unsatisfactory. For quantitative measurement of sensitivity, the magnitude of a silver deposit is determined optically by the amount of light which is transmitted or reflected. Density is expressed in terms of the light incident upon a negative and the light transmitted through the negative. The ratio of incident light to transmitted light is termed "opacity" and is the expression of the amount of light absorbed. Transmission is the ratio of transmitted light to incident light. *Density is the logarithm to base 10 of the opacity*, or *the logarithm of the reciprocal of the transmission.*

$$D = \log O = \log \frac{1}{T}$$

The conversion of density values to transmission values is simple. A density of 0.3 for example represents a transmission of ½ or 50 percent. A density of 0.6 has twice the opacity of a density of 0.3 and its transmission is ¼ or 25 percent. Figure 35 gives transmission values for a range of densities.

Density	0. 15	0. 3	0. 45	0. 6	0. 9	1. 0	2. 0	3. 0
Transmission (percent)	70	50	36	25	12. 5	10	1	0. 1

FIGURE 35.

The transmission value given is the percentage of incident light which is transmitted by a given density. From any density value, the transmission can be computed by finding the antilogarithm of the density value. This antilog can be found in a logarithm table and is the opacity value, of which the transmission is the reciprocal. The following problem shows the procedure for computing transmission from density value:

$$\text{density} = .75 \quad \text{antilog } .75 = 5.656 = \text{opacity}$$

$$O = \frac{1}{T} \quad T = \frac{1}{O} = \frac{1}{5.656} = .177 = 17.7 \text{ percent}$$

For complete understanding of density (exposure relations), a working knowledge of logarithms is essential but for manipulation of density values and subsequent computations, a knowledge of the use of logarithmic tables is sufficient.

161. Measurement of density.—*a.* The instrument used for the measurement of density values is called a "densitometer." There are many kinds of densitometers, but the principle involved is the same in each. The fundamental features of any densitometer are a source of light to provide the measuring beam which passes through the negative, a means of limiting this beam to the desired area of the negative, and a means of comparing the brightness of this beam with that of another from the same source which does not pass through any portion of the negative. In this way, a direct comparison is accomplished between the incident beam of light and the beam which passes through the desired area of the negative. A common method of comparison is to adjust the beam which *does not* pass through the negative until it is equal in intensity to the transmitted beam. The means of varying this beam which does not pass through the negative is calibrated to read density values. The density of a certain area can be read directly from this scale when the incident and transmitted beams are balanced.

b. Figure 36 contains a diagram illustrating a common principle of densitometry. It will be noted that the negative is placed on the stage *I*. Light from the source *A* is split into two beams, one passing directly through the negative to the eyepiece *J*, and the other beam traveling from the lamp to the mirrors *B*, *D*, and *E*, where it is reflected onto a split mirror *F*. It is reflected from this mirror to the eyepiece where a split field is observed. The wedge *W* contains an area *C* of gradient density. By rotation of the wedge, areas of different density can be interposed in the beam from the mirrors, thus changing its intensity. The split field in the eyepiece is balanced by rotating the wedge until the field of the beam which passes through the negative has been equaled in intensity by the proper variation of the intensity of the beam from the mirrors. The reading of density of the desired area in the negative is obtained from a calibrated scale on the edge of the gradient wedge.

162. Density exposure relation.—The relation between exposure and the photographic response of a material is usually presented in the form of a graphic curve in which density is plotted against the logarithm of the exposure. The exposure is generally expressed in terms of the illumination on the exposure plane of the sensitometer, as measured in meter candles, and the time of the exposure on any

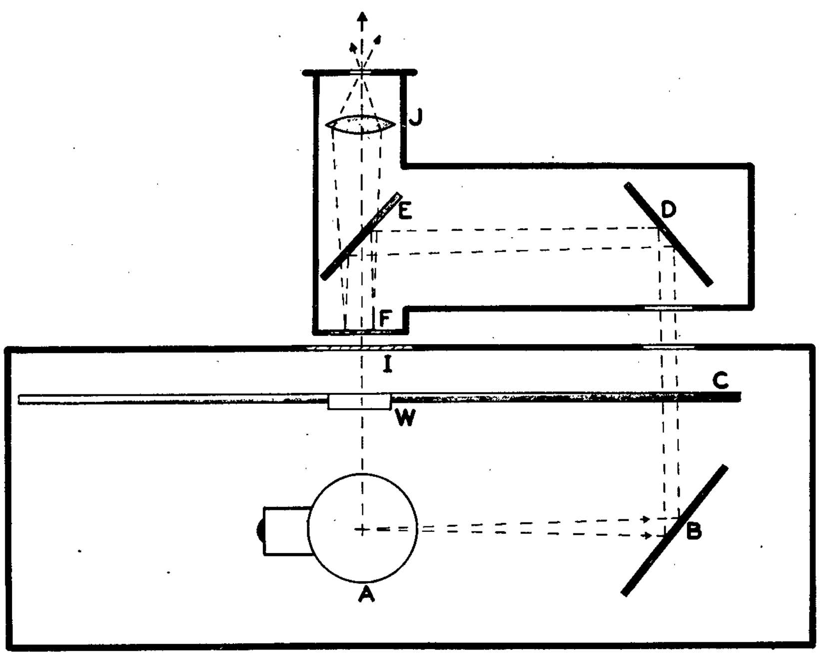


FIGURE 36.—Gradient wedge densitometer.

individual step in the strip. The resulting units of exposure are meter candle seconds. Graphically, each individual density is plotted against the corresponding exposure which produced it. A typical resultant curve is shown in figure 37.

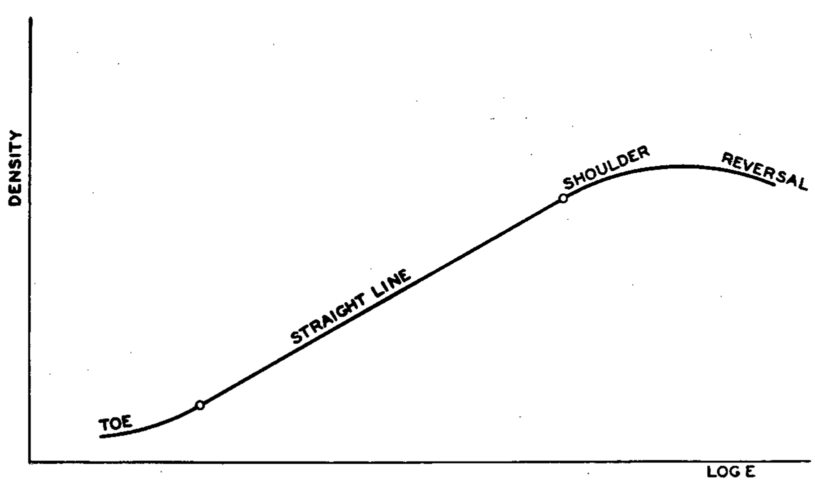


FIGURE 37.—*H* and *D* curve.

a. This method of expressing sensitometric data was developed by Hurter and Driffield and is frequently called the *H* and *D* curve, the characteristic curve, or the *D*-log *E* curve.

b. For the greater part of its length, this curve is a straight line. Throughout the straight line region, the logarithm of the exposure is proportional to the density produced. Since density is the logarithm of the opacity, it is evident that the opacity is proportional to the exposure within the straight line portion of the curve. The straight line then represents the region of correct exposure. Within this range, density increases proportionally with the logarithm of exposure of the logarithm of subject brightness.

c. The lower portion of the curve is called the "toe," and is concave to the exposure axis. There is no definite relationship between the exposure and density in this portion of the curve. The toe of the curve is widely used in making negatives, and is often referred to as the region of underexposure.

d. The upper portion of the curve, which is convex to the exposure axis, is called the "shoulder." The increase in density, with exposure difference, decreases steadily as exposure increases, finally becoming zero. This portion of the curve represents the region of overexposure.

e. Beyond the point where zero is reached, an increase in exposure will produce a decrease in density so that a positive would result instead of a negative. This is called the "period of reversal." This period would be the result of abnormal overexposure and has no practical value.

Section V

CONTRAST DETERMINATIONS

163. Effect of development.—An increase in the development time under given conditions of development will produce an increase in density, the increase being greater for the higher densities than the lower densities. This means, that for a given exposure increment, the density differences are increased. As the density difference increases, the angle between the straight line and the log exposure axis also increases. Since this increase in the angle represents a difference in contrast between densities, it is therefore a measure of the degree of development, and variation in contrast by development may be expressed in terms of the measure of this angle. Generally it is expressed as gamma and is the tangent of the angle, or the ratio between the difference of any two densities on the straight line and the difference in logarithms of the corresponding exposures.

a. When gamma is equal to 1.0, the density differences are equal to the differences in logarithms of the exposures on the straight line portion. In a photograph, these exposures are the direct result of brightness differences in the subject; therefore, with development to gamma 1.0, the differences in density are proportional to the logarithm of the brightnesses of the corresponding parts of the subject. The ratio of opacities then, since density is the logarithm of opacity, is the same as that of the representative brightnesses. With development to gamma less than 1.0, the opacity difference is less than brightness difference in the subject. When gamma is greater than 1.0, the opacity difference is greater than subject brightness differences.

b. The opacity differences determine the contrast of the negatives, therefore gamma is proportional to contrast when the maximum and minimum densities of the negative lie on the straight line portion of the curve. If some portions of the subject are represented by densities which are not on the straight line, then gamma does not represent the true contrast of the negative.

164. Determination of gamma.—*a.* The value of gamma may be determined by use of the formula:

$$\text{Gamma } (\gamma) = \frac{D_2 - D_1}{\log E_2 - \log E_1}$$

Draw two perpendicular lines from the exposure axis to their points of intersection on the straight line portion of the curve. Determine the densities at the points of intersection and substitute both density and log E values in the formula. The value of gamma may be found in this manner for any H and D curve (fig. 38).

b. In practice, a transparent scale called a "gammeter" is used to determine gamma. Figure 39 shows one form of gammeter commonly used in sensitometry. In use, the arrow is placed on a point along the straight line of the curve. The base of the gammeter is placed on a line paralled to the log E axis. The vertical axis of the gammeter will then be intersected by the straight line portion of the curve. At this intersection the gamma for the H and D curve is read from the calibrated scale.

165. Time-gamma curves.—Among other factors, gamma is a function of developing time and increases proportionally. If a series of sensitometric strips are developed under equal conditions for

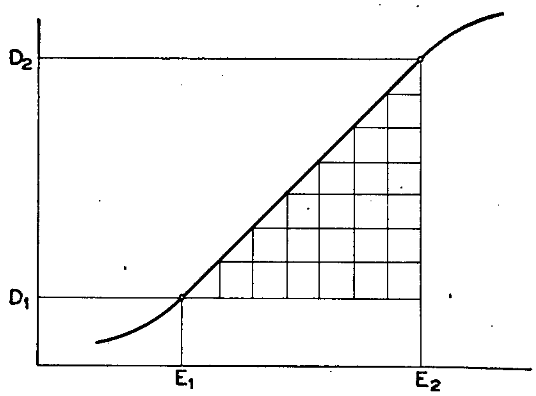


FIGURE 38.—Calculation of gamma.

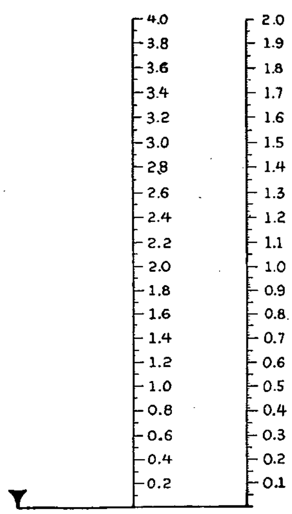


FIGURE 39.—A type of gammeter.

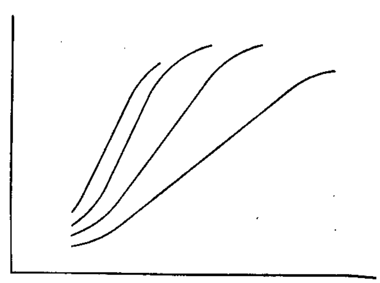


FIGURE 40.—Group of *H* and *D* curves showing gamma increase.

different times and the resulting densities of each strip plotted, the result will be a group of *H* and *D* curves of increasing gamma (fig. 40). If the values of gamma are plotted on another graph against developing times, the curve will show the relation between development time and gamma for the emulsion in use. This curve is called a "time-gamma curve" and from it can be determined the developing time necessary to produce any desired gamma for a specific material in the developer being used. Conversely, gamma can be read from the curve for a given developing time. (See fig. 41.)

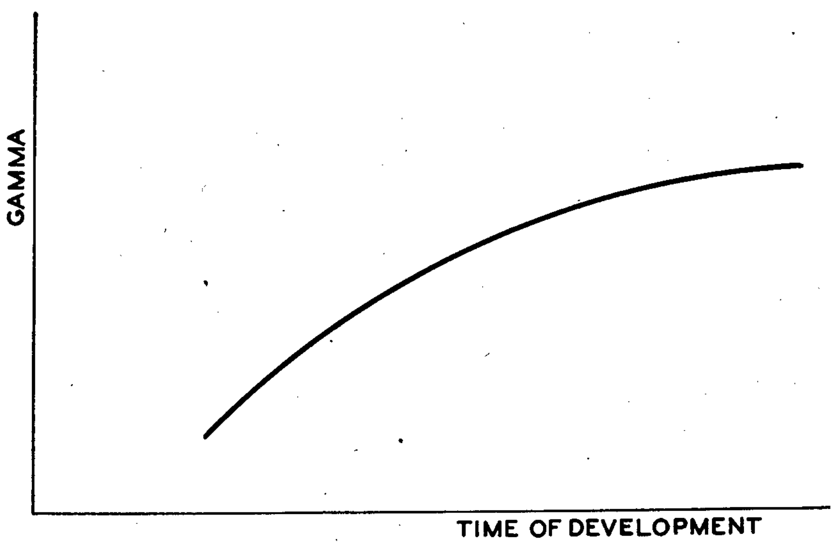


FIGURE 41.—Time-gamma curve.

166. Development latitude.—*a.* Occasionally it is not necessary to obtain an absolute gamma but certain tolerance may be allowed. Processing must be kept within limits and developing time must not exceed a given time or fall below a corresponding minimum. This range of developing time to produce a given tolerance in gamma is termed "development latitude."

b. Development latitude may be determined from a time-gamma curve when the tolerance in gamma is specified (fig. 42). It is a very important characteristic when sensitive materials must be developed to specified gamma as in the processing of motion-picture sound records.

167. Gamma infinity.—Contrast, or the value of gamma, increases with development time. This reaction is definite; that is, a certain point is reached, with prolonged development, where contrast no longer increases. Due to the addition of development fog, the value of gamma decreases beyond the point of maximum contrast. The reason is that the heavy densities have reached a maximum and further development builds up the densities of the lesser exposed areas thereby lowering contrast. This maximum available contrast is termed "gamma infinity."

a. The value of gamma infinity depends chiefly upon the sensitized material but varies to some extent with different developing agents.

b. Gamma infinity may be determined experimentally but since very

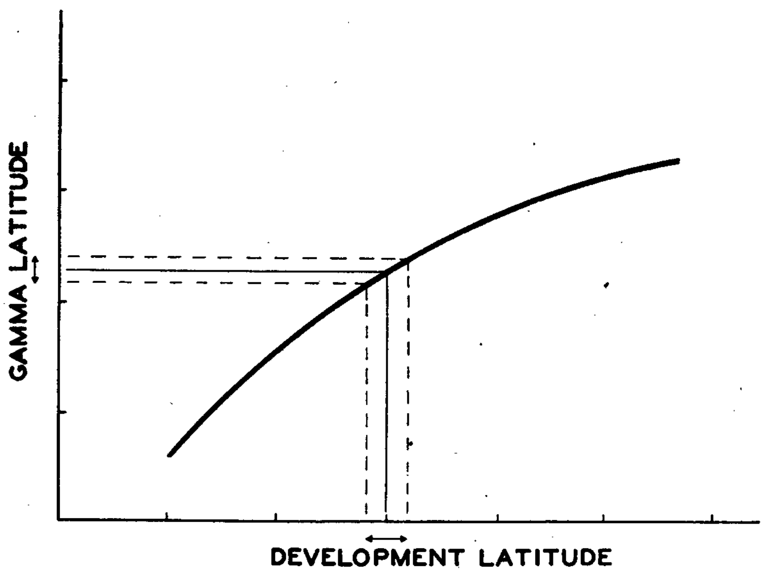


FIGURE 42.—Development latitude.

high densities are involved which may be fog due to long development, the process is subject to experimental errors. Gamma infinity is generally determined by calculation from lower values of gamma. Calculation of gamma infinity involves the use of two sensitometric strips, one of which is developed twice as long as the other. All other conditions of development are the same for both strips. For safety, the longer time of development is usually made short enough to avoid reaching gamma infinity in development. The following formula is used in computing gamma infinity:

γ is the symbol of gamma

$$\gamma\infty = \frac{(\gamma_1)^2}{2\gamma_2 - \gamma_1}$$

γ_2 is reached in twice the time necessary to obtain γ_1.

SECTION VI

MEASUREMENT OF SENSITIVITY

168. Emulsion speed.—Several methods of expressing emulsion speed exist and are widely used in photography. Absolute values of film speed have little significance since true speed or sensitivity depends largely upon processing conditions. Relative speeds have definite practical value since they present a direct method of comparing emulsions. By different methods, an arbitrary number to designate speed is assigned to each kind of emulsion. This number serves as an index to the relative speed of the emulsion. In each system, the number increases with the sensitivity, but the different systems are inconsistent and do not always produce results which are comparable with one another because different criteria are used in determining speeds in the various systems.

169. Speed determinations.—The most widely used systems of determining sensitivity of emulsions are based on four principles as follows:

a. Threshold speed.—(1) This method of determining speed is based upon the exposure necessary to produce the least perceptible density (fig. 43). A fast emulsion is one which will produce a perceptible density with relatively low exposure, and conversely, a slower emulsion will require more exposure to produce an equal perceptible density.

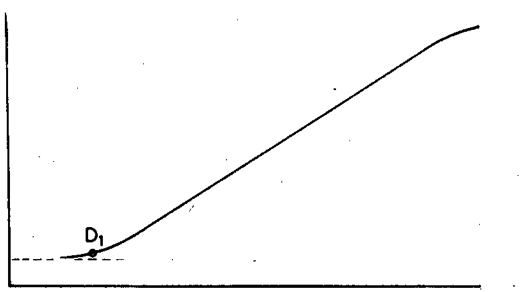


FIGURE 43.—Threshold speed.

(2) The most familiar speed rating based upon threshold speed is the Scheiner rating. Since there is no fixed relationship between threshold exposure and that required for satisfactory rendering of the gradations of the subject, the threshold exposure method is inadequate for measuring the effective speed of an emulsion.

b. H and D speed.—When the straight line portion of an H and D curve is extended to intercept the log E axis, an exposure is indicated which is termed the inertia (fig. 44). The reciprocal of the inertia indicates the speed of the material. This value is often less than unity so that it is customary to multiply it by some constant to obtain a convenient system of numbers. The number selected as the factor in the American system of *H* and *D* speed is 10.

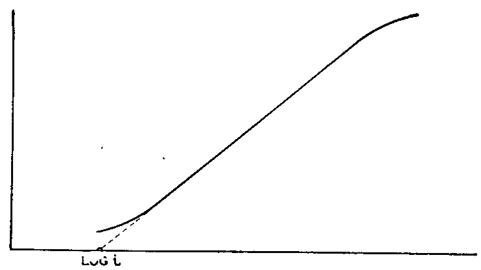


FIGURE 44.—*H* and *D* speed.

(1) If a developer contains bromide or the emulsion contains free bromides, the value of inertia varies with the degree of development. The intersection of the extended straight line of the characteristic curve with the log *E* axis shifts to the left as gamma increases. Thus the effective speed of an emulsion increases as development is prolonged. For each time of development there is a corresponding *H* and *D* speed.

(2) *H* and *D* speeds are indicated by numerical values which are directly proportional to sensitivity. For example, an emulsion rated as 1,300 *H* and *D* is twice as fast as one rated at 650 *H* and *D*.

c. Weston speed ratings.—(1) *General.*—A modification of the inertia speed rating (*H* and *D*) is the Weston method by which inertia and the latitude of the emulsion are considered. In this system, the speed is determined from the *D*-log *E* characteristic of the film which is processed to the value of gamma most often encountered in practice for that particular emulsion.

(2) *Method of computation* (fig. 45).—Emulsion speed is inversely proportional to the exposure required to produce a given density. The following formula is used to compute Weston speeds:

$$W=\frac{4}{e_n}$$

Where W=Weston speed number
e_n=exposure required to produce a density of $1.0\times$gamma

The density is multiplied by gamma to avoid any discrepancy in speed arising from slight variations in gamma and speed is then specified for that gamma. Miniature camera film is usually developed to gamma=0.8. Most other types of film are developed to gamma=1.0, or the gamma which reproduces subject brightness. In measurement of speed by the Weston system, the exposure necessary to produce the given density is determined from the D-log E curve of the desired gamma. Exposure in sensitometry is measured in meter candle seconds which is the exposure unit indicated on the D-log E curve.

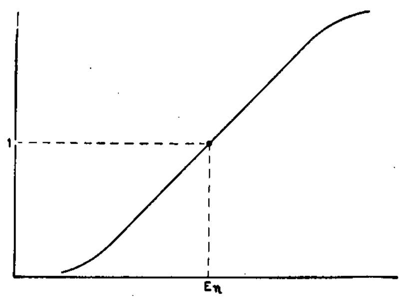


FIGURE 45.—Weston speed.

(*a*) If a particular film attained the specified density with an exposure of 0.125 meter candle second (M. C. S.), the calculation of the speed rating would be obvious from substitution in the formula, or $W=\frac{4}{e_n}=\frac{4}{.125}=32$ and the film has a Weston speed rating of 32.

(*b*) The light source in the sensitometer simulates daylight in its quality when the emulsion speed is to be determined for daylight. If the speed is to be measured for any other lighting, the quality of this light must likewise be simulated in the sensitometer.

d. Minimum useful gradient.—(1) In practice, the speed of a photographic emulsion is determined by the exposure necessary to reproduce the differences in brightness in the shadow portions of the subject. The speed, then, is determined by the exposure necessary to produce a suitable difference in density and not that required to produce any particular density. Differences in density determine the slope, or gradient, of the D-log E curve. The maximum gradient is attained in the straight line portion of the curve, and throughout this region the gradient is constant. There is no fixed gradient within the toe of the curve and the gradient decreases as the densities decrease. The point on the toe of the curve where the density difference is just sufficient to produce acceptable tone reproduction in the print is known as the minimum useful gradient.

(2) A common method of determining speeds by this principle

involves drawing the characteristic curve and selecting the exposure at which the gradient of the curve is 0.3 that of the average gradient for a log exposure range of 1.5. The origin of this exposure range is taken at the speed index point. (See fig. 46.)

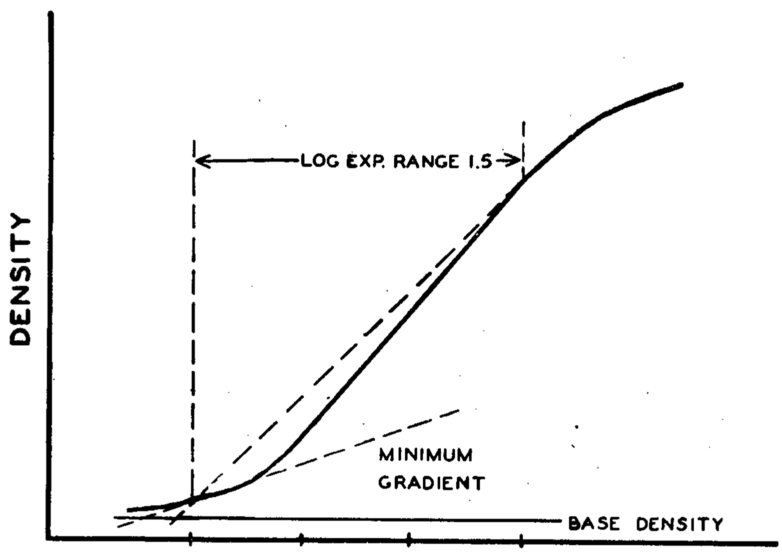


FIGURE 46.—Minimum useful gradient.

170. Latitude.—*a.* The scale of tones which can be reproduced by a film is known as the exposure range or exposure latitude. This range is indicated on a characteristic curve as the exposure interval between a point fairly low on the toe and another point located on the shoulder (fig. 47). As the brightness range in most scenes is considerably less than this exposure range, wide latitude is given in the choice of camera exposures. The latitude, or exposure scale, of a photographic emulsion is the range of exposures for which there is adequate density gradient for the desired result. While latitude is often associated with the straight line portion of the characteristic curve, normally a greater portion of the curve is used than the straight line.

b. Latitude is a very important characteristic of a sensitive emulsion because it indicates the range of brightnesses in a subject which can be satisfactorily recorded in a negative. The latitude of most negative materials is generally much greater than the range of brightnesses in a majority of subjects. The normal range of subject brightness is about 1-30 and only in exceptional cases does it exceed 1-100. Average latitude of negative materials is approximately 1-200, but is frequently considerably greater. The greater the latitude of an emulsion, the greater is the tolerance in exposure of the subject to produce an acceptable negative. For any given material, the greater the range of brightnesses in the subject, the less the tolerance in exposure. The selection of an emulsion to photograph a particular subject is greatly influenced by its latitude.

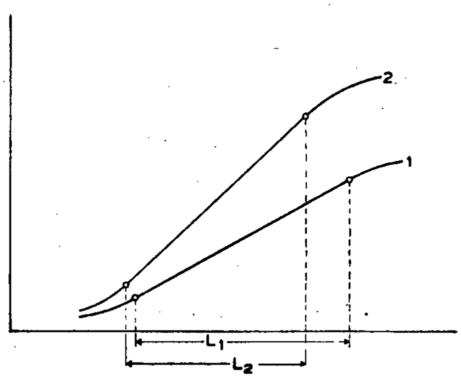


FIGURE 47.—Exposure latitude.

171. Spectral sensitivity.—The variation in the response of a photographic material with the wave length of the radiation to which it is exposed constitutes what is known as "spectral sensitivity," or as frequently termed "color sensitivity." The rendition of colors of a subject depends upon the spectral sensitivity of the emulsion in use. The measurement of spectral sensitivity involves the isolation of separate regions of the spectrum and determination of the response of an emulsion to the radiations within these regions.

SECTION VII

APPLICATION

172. General.—The principles and results of sensitometric determinations are employed in all branches of photography, but actual measurement of sensitivity is more or less limited to technical and scientific aspects. These determinations are used principally as controls in the production of accurate and consistent results. Every photograph is made under conditions which are determined in sensitometric work. The photographer selects an emulsion for a particular job, not haphazardly, but for definite reasons. If the subject has a great brightness range, he selects a film which has sufficient exposure latitude as determined for him by sensitometry. The speed of the emulsion regulates the exposure and an emulsion of suitable speed is selected for the subject. The particular type of lighting in use governs the selection of a material with appropriate color sensitivity. When the exposure is complete, the emulsion must be processed. Sensitometry again tells the photographer what developer to use for the particular emulsion to obtain proper tone gradation in the negative. He must know the degree of development necessary to reproduce the contrast of the subject as determined by the time, temperature, and condition of the developer. After the negative is finished, the next phase in the production of the photograph is to produce the positive. If the positive is on paper, the photographer must know what paper to use regarding contrast and tone and the conditions of development. It is unnecessary for any photographer to understand perfectly how all sensitometric measurements are made, but a complete understanding of the principles involved is an undeniable aid in the production of superior photographs. Proper selection of materials for particular or general work undoubtedly is the result of sensitometric principles. Fundamentally, similar problems confront every photographer in every branch of photography, so that sensitometry applies every time a photograph is made.

173. Practical.—Sensitometry is applied extensively in several branches of technical photography. Among these are the motion-picture industry, color photography, and the manufacture of sensitized materials.

a. Motion pictures.—(1) In the processing of motion-picture film, sensitometric methods of developer testing and control are employed exclusively. To insure the desired result in the projected image, it is essential that the materials are developed to a definite gamma. This can only be attained when the degree of development can be controlled, and is especially true in the case of processing sound track which is very susceptible to any change of development contrast.

(2) The time of development necessary to produce the desired gamma is determined by developing several sensitometric strips. These strips are developed to different times and the degree of development or gamma of each strip ascertained from the time-gamma curve which in turn establishes the time of development necessary to attain the specified gamma. If the desired gamma is not reached within a specified time, the developer is not sufficiently active and

replenisher must be added to bring the developer up to a standard condition or new developer made. In large scale production, tests are usually made at half-hour intervals.

b. Color photography.—(1) An example of the use of sensitometry in color photography is the production of separation negatives for color printing. These negatives are made with different filters and consequently must be developed differently to obtain equivalent results since development contrast varies with the color of light to which an emulsion is exposed. The determination of the degree of development of these individual negatives would be impossible by any other method than sensitometry. The filter factors for the particular emulsion must be accurately known to expose properly the negatives. These factors are easily and accurately determined by sensitometric means whereas any other method would be lengthy and inaccurate.

(2) Another application to color photography is the processing of Kodachrome film. While this processing is not influenced by the photographer, the importance of sensitometry is still evident. Kodachrome processing is rather complicated and delicate, and necessitates careful control. Sensitometric strips on Kodachrome are read by means of a color densitometer which has three gradient wedges of red, green, and blue, the primary colors. Three H and D curves are plotted for each strip. If the three coincide in the straight line portions, the color balance is that of a neutral gray. If the curve for any color varies from this coincidence in relation to the other two, it is evidenced by a sideward shift and the processing can be adjusted accordingly to obtain correct color balance.

c. Emulsions.—The most important application of sensitometry is in the manufacture of emulsions. Since the ordinary photographer seldom has facilities for making accurate sensitometric determinations, the manufacturer must do it. Every emulsion manufactured for professional and amateur photography is thoroughly tested. Complete recommendations are issued concerning all films, plates, or papers so that any photographer can intelligently use and process any emulsion. Understanding of sensitometric principles is invaluable to every photographer in his selection of a proper emulsion to fit a particular or general need and for intelligent and accurate processing. The photographer who makes superior photographs consistently, undoubtedly has a working knowledge of sensitometric principles.

CHAPTER 8

GROUND CAMERA PHOTOGRAPHY

SECTION I

GENERAL

174. Scope.—Ground camera photography embraces the making of any negative with a ground camera and its allied equipment.

175. Purpose.—Ground camera photography includes the making of photographs for the purpose of military intelligence, historical record, and technical information. It includes the photographing of airplanes or parts thereof, equipment, machine parts, construction work, buildings, military activities, personnel, etc. The cameraman will use the type of ground camera best suited for the purpose.

176. Types of cameras.—Ground cameras may be divided into three classes as follows:

a. View cameras.—View cameras are portable cameras generally used on a stand or tripod and have adjustments permitting restitution.

b. Hand cameras.—Small portable cameras that are held by the operator are hand cameras. They produce a smaller size image than the average view camera and since they are held in the hand, they can be used under conditions impractical with a view camera.

c. Copying cameras.—Cameras designed especially for photographic reproduction are copying cameras. Although usually portable, they are generally cumbersome and therefore not easily transported. Their use differs so much from that of the view and hand-held type cameras that a special chapter on copying (ch. 11) is included in this manual.

Section II

VIEW CAMERA

177. Setting up camera.—To use a view camera it should be secured to a tripod. For subjects such as landscapes, buildings, machines, and the like, the camera should be leveled. For special effects and some types of "close-up" work the camera may be placed at any desired angle. When so used special precautions must be taken to insure the rigidity of the camera and tripod.

178. Use of the sliding block.—The sliding block is a device to which the camera must be secured. It is adjustable to different positions on the camera track. When photographing close-up subjects at an acute upward or downward angle the sliding block may be used to change the position of the camera on the track, thus altering the scale of the photograph. It may also be used to balance the camera when a long bellows extension is used. It will also permit the location of the lens directly over the center of the tripod screw, facilitating panoramic exposures which overlap at a point of uniform scale by allowing the turning of the camera with the lens remaining on a common axis.

179. Movable lens board.—The lens board of a view camera should be provided with a mechanism which will raise and lower the position of the lens and also move it in a lateral direction. This feature is used for properly placing the image of the subject on the ground glass. The lens should not be shifted so far in any one direction that the image on the focusing screen will fall outside the accepted angle of illumination.

180. Use of vertical tilt and horizontal swing.—View cameras are equipped with a vertical tilt and horizontal swing. The vertical tilt is a device by which the ground glass can be tilted forward or backward on a horizontal axis. The horizontal swing is a device by which the ground glass can be swung forward or backward in a horizontal direction on a vertical axis. These devices are used for two distinct purposes; improvement of focus and restitution of the image. When either the vertical tilt or horizontal swing is used to improve the focus, the perspective is changed from the normal. Likewise, when used to improve perspective, certain parts of the subject will be thrown out of focus.

a. If a camera on the ground is focused at about midway to the top of a tall building, an inspection of the image on the ground glass will disclose the following:

(1) The image of the building is inverted on the ground glass.

(2) Both the lower part and top of the building are slightly out of focus.

(3) The vertical lines of the building converge toward the top.

b. The lower part of the building is out of focus because it is nearest the lens and will focus in a plane farther from the lens than the vertical plane of the ground glass. The top of the building is out of focus because it is farthest from the lens and will be in focus in a plane nearer the lens than the plane of the ground glass. If the vertical tilt of the camera is adjusted so that the bottom part of the ground glass is moved toward the lens and the upper part is moved away from the lens, the upper and lower parts of the image will approach sharp focus. An inspection of the image will reveal that while the focus is improved, the vertical lines of the building are more convergent than they were when the ground glass was in its original vertical position. If, on the other hand, the vertical tilt of the camera is tilted so that the top part of the ground glass is nearer the lens, the ground glass will be in a plane more nearly parallel to the vertical plane of the building and the vertical lines of the image will correspond more closely to the vertical lines of the building. (See fig. 48.) It will also be observed that the extremities of the image are not in sharp focus. As a rule, the lens aperture can be reduced sufficiently to bring these parts into sharp focus. If not, the distance from the camera to the building must be increased. If this distance cannot be increased, it is better to compromise the adjustment than to have any part of the image out of focus. If a camera is pointed downward on a subject, the same difficulties will be encountered but perspective will be exaggerated in the opposite direction.

c. In photographing a horizontal subject with the camera near one end, the effect will be the same but in a horizontal direction. In this case, the horizontal swing is used to remedy the difficulty.

d. There are occasions when the vertical tilt or horizontal swing must be used to secure sufficient depth of field with a sacrifice of good perspective. Often these camera adjustments are used to correct perspective at the expense of securing sharp focus, but generally it is possible to stop down the lens sufficiently to secure both good perspective and sharp focus.

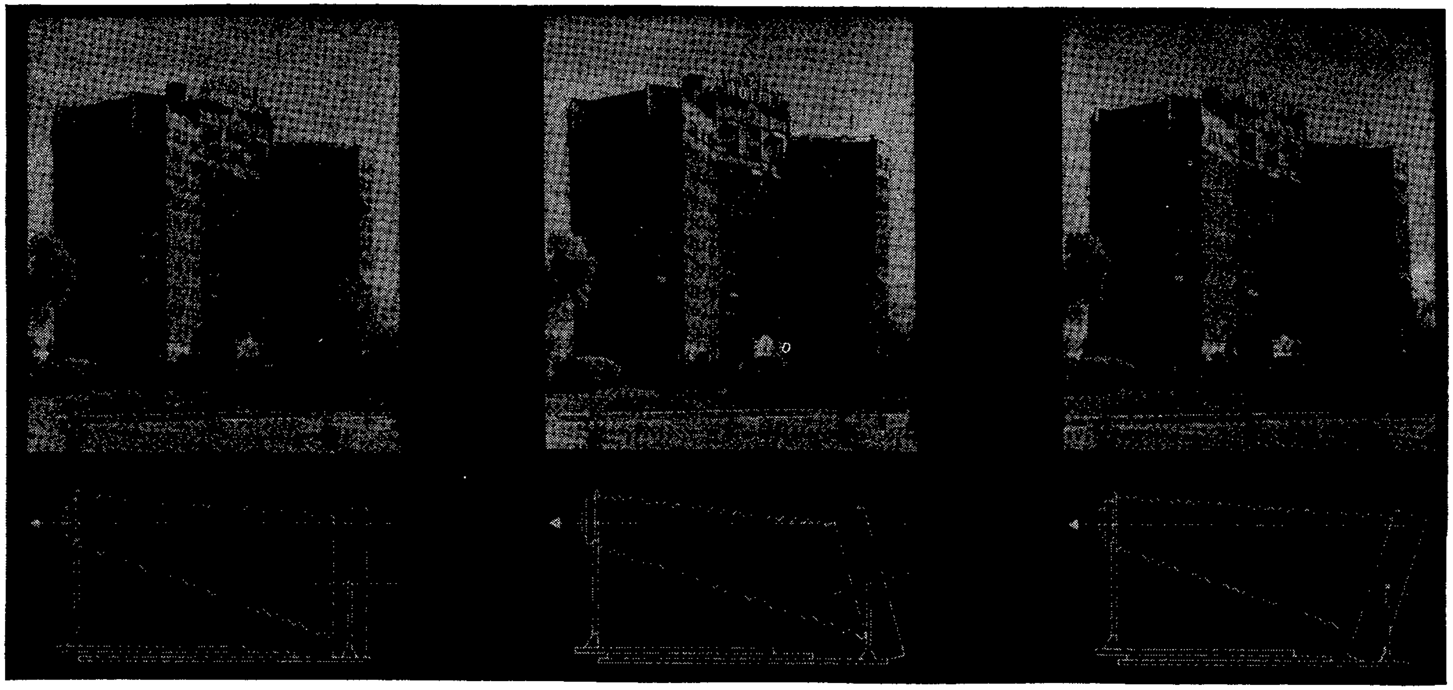


FIGURE 48.—View camera adjustments.

e. Some cameras are equipped with attachments which permit the lens to be tilted on both a vertical and horizontal axis. These adjustments are used for the same purposes as the vertical tilt and horizontal swing, but primarily for the correction of focus. They are also used in conjunction with this tilt and swing to give a greater range of adjustments for corrections. A camera that is additionally equipped with a tilting bed may be tilted upward or downward, permitting a better control of perspective through the proper manipulation of the "swings." Vertical lines can be made to remain vertical and parallel horizontal lines made to converge slowly or not at all. Thus a great depth of field is possible with the lens at full aperture, permitting exposures to be made at larger apertures with greatly improved accuracy of focus.

Section III

HAND CAMERA

181. General.—This type of camera is designed for general utility and will accommodate roll film, cut film, and film packs. These cameras are often fitted with both focal plane and between-the-lens shutters. When equipped with a lens-coupled range finder and synchronous photoflash, such cameras are useful for news, sport and informal group photography. The synchronized flash is often used as a supplement to daylight to illuminate shadows, in weak daylight, or at night when there is insufficient light for exposures. Being fitted with well-corrected anastigmat lenses from $f/4.5$ to $f/2.8$ maximum working aperture and having focal lengths from 3½ to 6½ inches, these cameras can be used frequently to obtain photographs that would be impossible with a view camera making 8- by 10-inch negatives and using a lens of 12 inches focal length.

182. Adjustments.—Focusing is accomplished for infinity by drawing the camera front outward until it reaches the infinity stops that are bolted to the bed track. These stops should not be moved from their set position. For distances less than infinity, the camera front is moved forward with the bed track by a rack and pinion device.

183. Accessories.—In addition to the synchronized range finder, the graphic type of hand camera is fitted with two view finders, the peep sight and the parallax. The peep sight (fig. 49) has two parts, one attached to the rear of the camera body and the other a wire frame attached to the camera front. If the wire frame and the rear sight are raised and the eye brought close to the rear sight, all that can be seen in the wire frame will be included in the picture. This type of view finder is very useful when making action photographs. The parallax view finder is a tubular device mounted at the top right side of the camera body. It has adjustment for parallax and provision in the front, which is removable, for accepting interchangeable masks for use with lenses of different focal lengths. The small dial at the back of the finder has markings which indicate distances corresponding to subject distance. To use the finder, set the dial to the figure most closely corresponding to the distance from the subject. If the subject is then centered in the finder, it should also be centered on the ground glass of the camera. It is recommended that the camera be mounted on a tripod and the ground glass image be compared with the finder image to see how closely the margins of each coincide. (See fig. 49.)

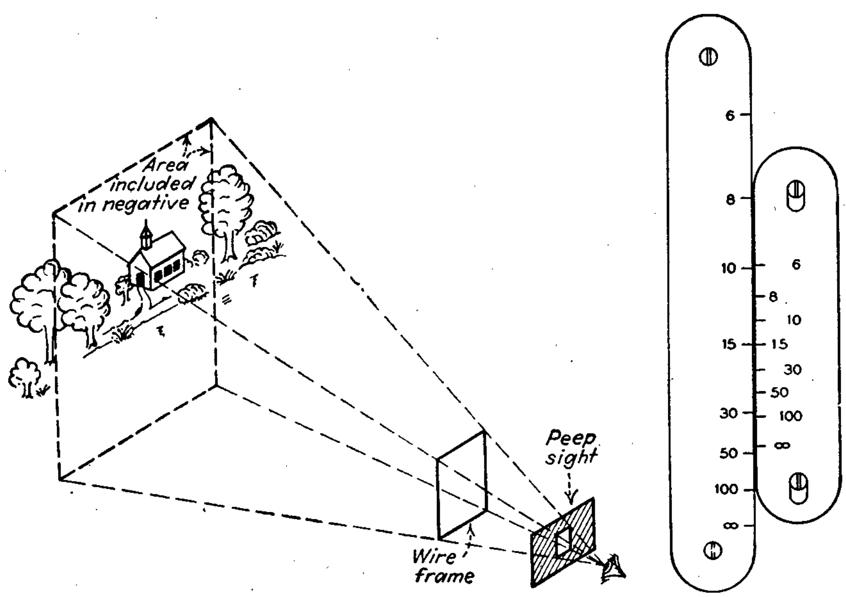


FIGURE 49.—View finder and Vernier focusing scale.

184. Vernier focusing scale.—The graphic type of camera is fitted with a special Vernier focusing scale (fig. 49) consisting of two parts, one on the camera bed and one on the movable track. To focus, pull the camera front outward until it rests against the infinity stops. Adjust both scales until the distances coincide with the camera-to-object distance at one of the scale markings. Intermediate distances can be proportionately estimated. This scale must be used only with the regular camera lens to which it has been adjusted. It is advisable that the lens aperture be reduced as much as prevailing light conditions will permit if depth of field becomes a factor, which must be considered.

185. Built-in shutter lock.—The purpose of this lock is to keep the focal plane shutter open and prevent its accidental release when the between-the-lens shutter is in use, such as for making synchro flash photographs. This lock is located directly below the shutter release lever and is released by winding the focal plane curtain or manually by pushing it forward.

186. Reflex type.—Another type of hand camera is known as the "reflex" wherein a mirror is placed at a 45° angle between the lens and the focusing screen. The purpose of this device is to show the image right side up on the ground glass and so be able to focus right up to the moment of exposure. The upper end of the mirror, being pivoted, is immediately released on pressing the shutter release lever to close the top of the camera thereby preventing light from fogging the film.

187. Range finders.—A valuable accessory to any camera is a range finder by which the operator is able to measure accurately the distance from the lens to the object. The lens-to-film distance may then be set by means of the focusing scale. If the range finder is lens-coupled, the act of measuring the distance automatically sets the lens film distance. In some range finders, the field of view is divided, one-half being displaced when the field is not in focus. In others, two complete images are visible until the correct adjustment is obtained. Like all mechanical instruments, range finders, especially when lens-coupled, sometimes get out of order and become inaccurate. Periodically, the accuracy of the range finder should be visually checked on the ground glass of the camera. If the camera is not fitted with a ground glass focusing screen, a sheet of ground glass may be placed in the back of the camera so that its surface is in exact register with the focal plane.

SECTION IV

COMPOSITION

188. Purpose of composition.—*a. Definition.*—Composition is the arranging and spacing of objects in a photograph according to the laws of harmony and proportion, or proper arrangement of material to be photographed.

b. Method.—The proper arrangement of the image on the focusing screen is one of the most important operations in taking a photograph. In composing the photograph, the cameraman's task is essentially one of selection and arrangement of parts through the choice of such a viewpoint and such conditions of lighting as will produce the effect desired. He begins with an empty space, the boundaries of which represent the margins of the photograph he is about to take. His problem is to arrange the image of the subject on the ground glass so that the thought he wishes to convey is clearly and unmistakably portrayed. Every photograph should have a readily recognizable subject and it should be possible for anyone seeing the photograph to understand why it was made and exactly what it illustrates.

189. Fundamentals.—There are three generally accepted fundamentals of composition; simplicity, point of interest, and balance.

a. Simplicity.—Simplicity means that the purpose or interest of the picture is readily recognizable and that it is not confused with a mass of surrounding objects and lines that would compete with or detract from the point of interest. For example, a person is being photographed in a garden. There are trees, flowers, shrubs, a pond, and a garden seat. If the person appeared small in the picture and no more prominent than the mass of surroundings, the composition would result in a confusion of purpose as to whether the picture represented the garden scene or the person being photographed. If the person is looking into the pond or resting on the seat, only enough of the garden should be included to support the composition. A less pictorial example of simplicity would be an object such as an automobile in front of a building. Simplicity of composition would result if there were no other objects on the ground surrounding the automobile. It would also contribute to an understanding of the picture and its purpose in showing that the automobile is the subject of the picture, if the building in the background is slightly out of focus. This will avoid lines in the background conflicting with the lines of the automobile and thereby emphasize the fact that the automobile is the purpose of the picture.

b. Point of interest.—Every picture should have a definite point of interest which should be outstanding in the composition and show clearly why the picture was made. The point of interest, also described as the subject, is best located when it occupies a position other than the center of the composition, preferably slightly below and to the right of the center. In addition to the location of the point of interest, its importance should be emphasized or supported by the lines of the picture. A line that emphasizes leads the eye to the point of interest and consequently is known as a "leading line." It is best located when entering the picture a little above either of the lower corners. It is unnecessary that a leading or supporting line be a definite demarcation. It can be a part of the picture that suggests direction toward the point of interest.

c. Balance.—A balanced composition is one in which the disposition of various features in a photograph gives harmony to the whole setting. Balance of composition is not accomplished by equality of mass or bulk on each side of the picture, as might be supposed. A composition is in balance when a large object on one side of the picture, preferably the right side, is opposed by a smaller object of similar nature on the opposite side. For example, a view of a building including trees will be in balance if a tree occupying much of the right-hand side of the picture is balanced by a tree or group of small trees occupying about one-third of the left-hand side of the picture. When the smaller balancing object is on the left, it is less likely to block or interfere with the leading line or entrance into the picture. Balance can also be suggestive, such as areas of sunlight or shadow, but in general solid objects are preferable. Whatever method is used to balance a composition, the balancing objects should not be too prominent or in competition with the main object or purpose of the photograph.

190. Factors of good composition.—The following basic factors of composition apply to most types of photographs:

a. The size of the image must conform to the picture space.

b. The point of interest should be slightly below and to the right of center.

c. The subject should appear as if entering the photograph.

d. Lines of the photograph should support the main point of interest.

e. Lines of the background should not be in confusion with lines of the subject.

f. Light or dark areas, especially when near the margin of the picture, will attract the eye and should not be in conflict with the point of interest.

g. The background should not be prominent.

SECTION V

EXTERIOR SUBJECTS

191. Composition.—While the general rules of composition given in paragraph 190 can be applied to all types of subjects, there are certain rules that are applicable when photographing specific subjects.

a. Building.—In photographing a building, a viewpoint should be selected that will show one side as well as the front. This will indicate solidity and will show both the depth and the width of the building. In this respect, a direct view of the corner should be avoided. A high viewpoint, or one from the full extension of the tripod, is preferable and should be such that the entrance will not be obstructed. The foreground should be in good focus and of sufficient depth to furnish ample support for the building. A foreground that is too deep will tend to give the building an elevated appearance and conversely, if the foreground is too narrow, the building will lack support. The background should be unobtrusive and usually out of focus to prevent confusion of lines of objects with the lines of the building.

(1) Vertical lines of the building should appear vertical in the photograph.

(2) The lens should be of as long focal length as the available distance of the camera from the building will permit to avoid abnormal perspective.

(3) Cross lighting will show the architecture of the building to the best advantage.

(4) A tall building should be composed vertically in the photograph. The converse is true if the building is wider than it is tall.

b. Mechanized equipment.—Mechanized equipment includes tanks, combat cars, automobiles, and trucks. A subject of this type should be photographed from an angle which will give more prominence to the side than to the front, the viewpoint selected being sufficiently toward the front to indicate its width and show important features.

(1) A low viewpoint will give the best perspective, show the machine to best advantage, and minimize background lines.

(2) The lighting should be from behind the camera and toward the subject.

(3) When possible, the front wheels should be turned at an angle about 10° toward the camera. If this can be done, the front wheels will appear straight in the photograph.

(4) Doors and windows should be closed.

(5) A background that is plain or not too prominent is desirable.

(6) The foreground should be sharp, preferably of good density, and of sufficient width to appear capable of supporting the machine.

(7) A long focal length lens should be used. A single element of a convertible lens is preferred.

(8) In addition to the use of a long focal length lens, distortion should be corrected by the use of the horizontal swing or vertical tilt.

(9) The subject should appear as entering the photograph. For this purpose, the rear of the machine will be nearer to the margin of the picture than to the front.

c. Airplanes.—The background should be plain or out of focus to avoid confusion of lines with those of the subject. The darkened interior of a hangar will usually make a good background if the airplane is placed in the opened doorway. More often the sky will form part of the background. In such case, the light from the sky should be regulated by the use of a filter. Cloud effects will thus be preserved and enhance the appearance of the photograph.

(1) A front viewpoint should be selected and should be at such angle that the tail assembly and identification can be plainly seen.

(2) All propellers and at least part of each motor should be shown.

(3) The camera should be at a height that will permit the wings to cover as much of the horizon as possible.

(4) The horizon should be level even at the expense of having the airplane tilted in the photograph.

(5) The ends of the wings should be very close to the limits of the picture space.

(6) Propellers having two blades should be in horizontal position. Propellers having three blades should have one blade pointing directly toward the ground.

(7) Ordinarily the undersurface of the wings and fuselage are weakly illuminated. Exposure must be sufficient to give detail in these parts of the airplane. It is advisable to supplement illumination in these areas by the use of reflectors.

d. Machine parts.—Parts of machines are often photographed both in their assembled position and apart from the machine. These photographs are made for the purpose of showing installation, defect, breakage or wear of a particular part, or to assist in description, identification, and replacement of the part. The details of the part should be sharp and well defined, and if a moving part, its mechanical operation in relation to adjacent parts should be evident.

(1) Identification of the part such as by number, letter, or word, if any, should be clearly shown.

(2) All detail necessary to the photograph must be sharp, clear, and well-defined.

(3) When the particular part is difficult to discern because of surrounding objects it may be isolated by placing a cardboard, cloth or blotter to serve as background. This effect may sometimes be achieved by using a depth of field that includes only the particular part.

(4) When a photograph is required that will show only a broken or damaged section of the object, the defect itself is the subject and should be so considered in the composition, focusing, lighting, and exposure.

(5) In bright light, the natural contrast of the subject may be so great that proper exposure of the shadows is impossible without overexposure of the highlights. In such instances, a screening of the light to reduce the natural contrast is advisable. It may also be necessary to reflect light into the darker areas to secure shadow detail.

(6) The use of a reflector may give too broad a light which will also cover the highlight area too much. This necessitates the use of a small focusing spotlight or a pocket flashlight to illuminate the shadows alone.

e. Crash photographs.—Photographs are always made of airplane crashes to assist in determining the cause of the accident, any structural weakness, or for preservation of evidence. To cover such an assignment properly, the following photographs should be made:

(1) A general view of the crashed airplane showing its identification number and insignia if possible.

(2) Several photographs of damaged sections, particularly those parts which might show the probable cause of the accident.

(3) Any landing marks which might assist in analyzing the accident.

(4) Any damage to surrounding property which might result in a claim for damages.

(5) All negatives made should be on as large a scale as possible.

192. Groups.—Military personnel may be photographed in either formal or informal groups.

a. Formal.—The senior officer or distinguished person will be placed in the center and other officers or personnel will be placed to right and left in order of rank. However, whenever a group of the same rank or grade is being photographed, the persons may be arranged according to height, with the taller in the center. When the group is large, it should be divided into rows and placed at different levels. The space in individual rows will be such that the faces of those in the rear will not be shaded or obscured. It is essential that uniformity of position of headdress, legs, feet, and hands be preserved.

b. Informal.—(1) An informal group is not arranged or posed in any particular order; the persons may be occupied in some general manner and not looking at the camera. For this type of photograph, a hand-held camera producing a 4- by 5-inch negative is commonly used, the negative subsequently being printed wholly or in part by enlargement.

(2) Large groups of 100 or more persons are best photographed from an elevation of about 8 to 10 feet from an extension tripod, the roof of a truck, or other suitable height.

c. Lens focal length.—In photographing a group, the lens should be of sufficient focal length to insure that the persons in the rear of the group will not appear in perspective appreciably smaller than those in the front and will be within the vision of ordinary perspective. For example, a 12-inch lens is ordinarily used for a group up to three or four rows. With six rows, a 15-inch lens is necessary for uniform scale.

d. Location.—Any group should, if possible, be located in shade. If shade is not available, the group should be located in such position that the members will not be facing direct sunlight. If the camera must face the sunlight or be at an angle to it which will allow direct rays of the sun to enter the lens, the lens must be shaded.

e. Camera viewpoint.—The camera should face the center of the group with the lens at or a little above eye level with persons in the front row. The attention of all persons should be directed to some point indicated by the photographer at the moment of exposure.

f. Exposure.—As brevity of exposure is an important factor, everything must be done to secure such desirable result. For example, select a high speed film of long scale of gradation; supplement daylight with flash if necessary; focus accurately on a point approximately two-fifths of the distance into the depth of the group itself with the lens at full aperture; and stop down the lens diaphragm only enough to secure sharpness of focus throughout the depth of the group.

Section VI

INTERIOR SUBJECTS

193. General.—While the general rules of composition (par. 190) apply to a considerable extent in the photography of interior subjects, there are certain directions that should be followed when photographing such subjects because of the inherent characteristics. Interior photography usually requires the use of artificial light as either the principal or auxiliary source of illumination.

194. Buildings, halls, rooms.—Photographs of interiors of buildings are required for the purposes of showing construction, repair, or alteration, and for historical record.

a. Selection of lens.—For this type of interior photography, the selection of a lens having the correct focal length that will properly portray the subject is very important. For instance, if the subject is a hallway that is much longer than it is wide, a lens of at least 12 inches focal length should be used for a negative 8 by 10 inches. If the subject is a room or an interior of average proportions, that is, a little longer than it is wide, a much shorter focal length lens should be used. In this case, a wide angle lens of about 6½ inches focus for an 8- by 10-inch negative will be satisfactory.

b. Composition of the photograph.—(1) Vertical lines must appear as vertical in the photograph.

(2) Avoid horizontal lines that extend across the picture.

(3) Other lines should support the point or object of interest.

(4) Show three walls, ceiling and floor, the upper part to be about two-thirds and the lower part about one-third of the picture area.

(5) The viewpoint should not be directly toward a corner except for some special purpose; even then the corner vertical line should not center the composition.

(6) There must be an entrance into the picture. If possible, show an exit also. An entrance is any unobstructed pathway leading into the picture, not necessarily a door or arch.

(7) Avoid large objects in the foreground that may be out of focus or detract from the main object or point of interest.

(8) The main object or point of interest should seldom occupy the center of the composition.

195. Personnel.—*a. General.*—The photography of interior subjects is often required to include persons who are occupied in some manner. For such pictures, large floodlights of sufficient power to allow instantaneous exposures are sometimes used. The method that will require the least operating equipment is the use of a hand camera fitted with synchronized photoflash.

b. Composition of the photograph.—Select a viewpoint that will show to the best advantage how the personnel is occupied. All persons should be giving their attention to the work they are performing and not be looking at the camera at the moment of making the exposure.

(1) The point of interest should be clear and well-defined.

(2) Sufficient surrounding area should be included to support the main feature or point of interest.

(3) If the distance from camera to subject will not permit the composition that is desired in the final print, the negative may be masked to obtain the desired composition in printing.

196. Airplanes and airplane parts.—*a. Airplanes.*—While it is unlikely that a photograph of an entire airplane will be made inside a hangar, the same rules of composition would apply as for exterior airplanes. The general illumination within the hangar may be aided by the use of one or more portable lights to assist in the illumination of the darker areas.

b. Airplane parts.—The photographing of parts of airplanes while in a hangar is of considerable importance. Such photographs are made chiefly for the purpose of illustrating technical reports. This type of photograph must show the following features:

(1) The part itself in sharp, well-defined detail.

(2) Its operation and relation to surrounding parts.

(3) Surrounding parts (especially the background) that are not essential to the purpose of the photograph should be out of focus, if possible, or eliminated entirely.

(4) Any letters or numbers, and like features that will identify the part.

c. Equipment.—(1) *Lens focal length.*—When it is desired that an 8- by 10-inch negative be made, the camera should be equipped with a lens of 12 inches focal length. For a 4- by 5-inch negative, a lens of about 6 inches focal length will be suitable.

(2) *Illumination.*—It generally will be found that the existing light of the interior of a building results in a deficiency in illumination of the darker parts of the object. This in turn will mean a considerably prolonged exposure for shadow detail. If the subject is one in which the highlights are prominent, it may not be possible to prolong the exposure for the dark parts without overexposing the highlights. A reflector may be some help in such cases. However, the best controlled system of lighting, and the one easiest to calculate the correct exposure, is by the use of a small portable floodlight in a reflector that can be moved to different positions in relation to the object.

d. Operating directions.—(1) *Depth of field.*—When the part to be photographed has a greater depth of field than 5 inches, it is not advisable to attempt a 1 to 1 scale when making the negative. The distance from the lens to the object should be increased so that a slightly reduced scale will result. This reduction can be projected to a larger scale, if necessary, when making the print.

(2) *Focusing.*—In focusing the image on the ground glass, it is important that a point two-fifths of the distance into the depth of the object be focused sharply at the full lens aperture. Unless this point is carefully selected, the front or rear of the object may still be out of focus when the lens is stopped to its smallest aperture. After the determined image scale has been focused on the ground glass and the lens aperture reduced to give the necessary depth of field, the extremities of the object are carefully examined on the ground glass by strong lighting for critical sharpness.

(3) *Position of floodlight in relation to the object.*—Light is reflected from any bright surface at the same angle as the incident light to that surface, and consideration must be given to the angle of lighting in order to avoid "flare" which will result on a negative whenever strong light strikes a lens.

(4) *Concentration on the object.*—It is always necessary that the photograph of the object itself be free from confusion of lines in the background or other parts not directly related to the main objects. This result can sometimes be achieved by using a lens aperture that will give the necessary depth of field in the object and still not place the background in sharp focus. This is not always possible if the background is close to the object. In such instances, a sheet

of cardboard, a focusing cloth, or similar article may be used as a background. Should these practices fail to accomplish the result desired, the only remaining recourse is to block out the undesired portions of the negative which in itself is a difficult operation requiring much time and skill.

197. Installed machinery and equipment.—*a.* Photographs are required of machinery, especially newly installed machines, for historical records, reports, and similar purposes. The following features should be shown:

(1) The viewpoint should be such as to show the front of the machine and some of the side.

(2) Show as clearly as possible the working parts and power source. If the machine is powered by a belt from line shafting, it is not necessary to show the line shafting.

(3) If it is required that operation be shown, one or more mechanics should assume a natural pose of attention to the machine and not look toward the camera.

(4) The photograph should be free of interferences from surrounding objects and background as much as possible.

b. General operating considerations.—Photographs of this nature usually require that the machine be isolated or free of interferences. If the installation is at a sufficient distance from the background, confusion of lines from that source will be avoided if the background is out of focus. When this is not possible, a white background should be placed behind the object and illuminated by two floodlights that are completely independent of the illumination used to photograph the machine itself. If such background is not perfectly plain or shows creases or other marks, such can be eliminated if the background is kept in motion during the exposure. A plain white floor ground should be used if the machine is not mounted as a fixture. Otherwise the floor area must be blocked out in the negative. Windows or any kind of illumination in the rear of the object should be blocked out entirely or the photograph made at night.

198. Engineering or small object photographs.—*a. General.*—Military photographs occasionally are required of small metal objects, such as component parts of a pistol or machine gun, or aircraft parts to accompany a technical report or requisition. Such photographs must show the object as fully as possible, particularly working parts, and should indicate a number, letter, or other mark that will assist in identifying the object or part.

b. White background.—(1) *Purpose.*—The objects required to be photographed will range in size from small springs, bolts, etc., to objects 8 inches long and 5 inches deep. Some form of isolation should be used so that very small parts will appear clearly in the photograph regardless of the fact that some of these parts may be dark or black, and some bright or white. For this purpose, a white background is used to isolate the part from what would otherwise be background interference, whether the part itself be white or black. The white background is photographed at the time the negative is made. This eliminates the necessity of attempting to block out the negative and isolate the part by hand work.

(2) *Photographing the object.*—For all objects other than those requiring special treatment, such as indirect lighting or the use of one or more pola-screens, the method of operation is the same in all respects as for indoor photographs of machine and airplane parts, with the exception that the object is supported at a distance from the background.

(3) *Photographing the background.*—At the conclusion of exposure for the object, it is an entirely distinct operation to photograph the background. The object is elevated or placed on a support at a distance of 6 to 8 inches from the background. If it is practicable to increase the distance between the object and background, it will be easier to obtain sufficient density in the negative to have it appear white in finished print without getting halation or impairment of the outline of the object. The method of photographing the background is very simple in itself but requires extreme care in its operation. The procedure is as follows: Bring the floodlight to a position about 8 inches above the background, at the same time tilting the reflector at such an angle that the light illuminates the background but does not strike the object (fig. 50). While maintaining this position, keep the light moving around the object so that the whole ground gets even illumination. Using the type film and floodlight previously indicated, the exposure for the background will vary in duration from 1 to 2 minutes according to the operating distance of the floodlight when making the exposure for the object. When the object is such that it can be supported at a distance from the background, the above procedure will give a perfect light-resistant negative background, saving all the time and effort necessary to block out the ground by hand work.

(4) *White backgrounds for very small objects.*—In many instances, it is required that a photograph be made of an object and the parts composing its interior. The interior parts may be so small and numerous that it is impossible to support them all at a distance from the background. In such cases, placing the objects on an elevated sheet of glass is not practicable. The best method of obtaining the desired photograph is to place the objects on a white ground in their proper

order. A single floodlight is used at a distance of about 5 feet and is kept moving around the objects during the exposure to prevent the shadows registering too strongly. In this case a perfectly white background cannot be obtained. The light gray effect should not be objectionable.

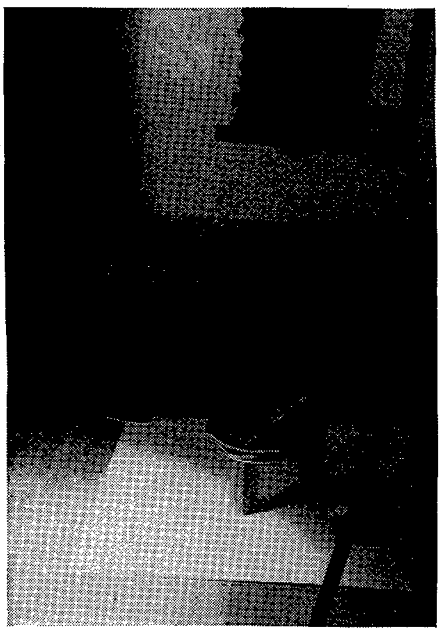


FIGURE 50.—Illumination for engineering photographs.

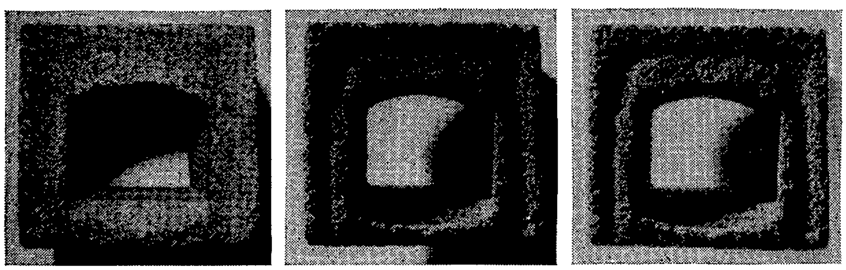
c. Using two floodlights.—When a large number of small object photographs are required, a single floodlight used as the illuminant will make the operations too slow. Good negatives may be obtained by placing two 2,500-watt photo floodlights in reflectors, one on each side of the objects, at distances of about 6 feet. These lights should be mounted on adjustable stands and elevated to a height so that the light will be directed toward the objects at an angle of approximately 45°. Exposures in this case will average between 20 and 30 seconds at $f/45$.

d. Use of indirect and diffuse lighting.—Certain objects having bright surfaces that reflect light from many different angles cannot be photographed by any direct lighting without one or more such surfaces producing "flare." The use of such things as putty or condensation of atmospheric moisture to dull such surfaces is inadvisable. The method of using indirect lighting from a reflector is satisfactory in the case of a flat surface, but this type of lighting is not suitable for uneven surfaces that reflect light at different angles in widely varying intensities. Such conditions are best met by using diffused light. To accomplish this, the bright object is enclosed in a transparent paper compartment called a "tent." This will prevent the object from showing any reflections of surrounding objects and permit easy control of highlight reflection. The object is placed in the tent which is completely closed except for a small aperture through which the camera lens projects. The lighting system which may consist of one or more floodlights is manipulated from outside the tent to produce the desired effect.

e. Photographing glass objects.—Glass objects may be photographed by either diffused lighting or by direct lighting, depending on the nature of the object. In either case, the appearance of the glass will be best preserved if the light source is directly above or at a slight angle to the object depending upon whether the object is flat or curved.

f. Use of light box.—A light box is an apparatus with an interior that can be illuminated. A diffused glass lid or top serves the purpose of a platform on which small objects may be placed. The objects are photographed without the interior of the box being illuminated. On completion of this exposure, the interior of the box is illuminated to give the exposure for the white background. The advantages of this method are its simplicity of operation and convenience. The main disadvantage is that for objects having convex sides or surfaces, the outline of such objects will be weakened or lost completely due to the fact that they are in contact with the illuminated surface.

g. Photographs to show texture.—(1) It is sometimes required that the texture of objects such as fractured metal, fabrics, tile, brick, etc., be clearly shown. The success of the photograph depends upon correctly judging the angle of light to the object so as to get the proper cross lighting. The best method of illumination is to use a single floodlight, raising and lowering the light until a position is determined that will show the full form of the texture. In the required position, it will be observed that the cross lighting produces strong contrast between high lights and shadows with practically no halftones. This will result in shadows appearing with insufficient detail. To overcome this defect, a second floodlight of the same type is used on the shadow of the object at double the distance of the opposite light. The exposure for this secondary light at the stipulated distance will be approximately an additional one-sixth of the exposure. For example, if the exposure is found to be 5 minutes, the exposure for the secondary light will be 48 seconds, or a total exposure of 5 minutes, 48 seconds, to give necessary shadow detail and full texture rendering. (See fig. 51.) By a study of figure 51 it will be noted that a flat lighting fails to register the general contour of the subject; that a distinct cross lighting results in blocked shadows, but that a texture lighting (a cross lighting aided by a secondary light used so as to increase shadow exposure) will permit the registration of both texture and contour.



① Flat lighting—no texture. ② Cross lighting—shadows blocked. ③ Texture lighting—detail in shadow.

FIGURE 51.—Cross lighting to show texture.

(2) If the object to be photographed is a piece of broken metal that has a sparkling or bright crystalline texture, it is important to use a nonhalation emulsion and also to increase the distance between the floodlight and the object.

199. Groups.—While groups of people are usually photographed outdoors, circumstances sometimes make it necessary that this work be done inside a building.

a. Composition.—Composition and arrangement of the subjects follow the same rules as for outdoor groups, whether formal or informal.

b. Lighting and camera equipment.—(1) Exposure time should be as brief as possible. For formal groups, floodlighting is best and should be of sufficient volume to permit an exposure not exceeding 1/5 second. Another advantage is that the group can be observed under the light condition by which the negative will be made and checked for balance or evenness of illumination.

(2) If a synchronized flash is used, two or more photoflash lamps should be so placed as to evenly distribute the light over the area to be photographed. Avoid the use of a single flash at the camera position as it will result in a greater exposure at the center of the group. A lighting of this sort will be flat at the center with a

gradual verge toward cross lighting as the extremities of the coverage of the flash are approached.

(3) If the subject is to be photographed with an unsynchronized flash mechanism, place the flash equipment in position as in the above described case. Focusing may be necessary with the aid of a light or bright object placed at a suitable position within the area to be photographed. Prior to exposure the shutter should be set for "time," and the room darkened as much as practical. To make the exposure the lens should next be opened and the flash made, followed by an immediate closing of the lens. If the lens is opened for a prolonged period either prior to or following the flash, a troublesome exposure may be had by the general illumination within the room, which will result in movement in the photograph.

SECTION VII

IDENTIFICATION PHOTOGRAPHS

200. Definition and use.—An identification photograph is one made for the purpose of establishing the identity of a person. Photographs of this type are used on identification cards, file cards, official records, or passports.

201. Placing the subject.—The subject may be either standing or sitting and must face the camera in such a way that a full front view photograph is obtainable. He should be 5 feet from a white or light gray background. The subject should be relaxed and not possess a fixed expression either in the form of a grin or a too stern countenance. The hands should be at the sides and the uniform correctly worn, minus headgear. When several persons are being photographed, positive identification is obtained by photographing an identification card which is held in a suitable manner by each individual photographed.

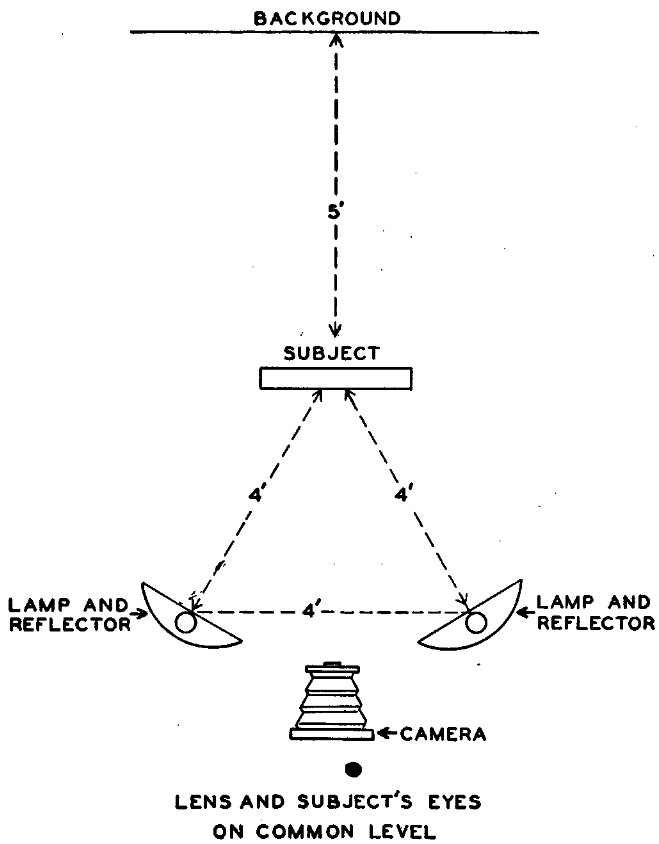
202. Camera.—The camera should be adjusted to a horizontal position and at such a height that the lens and the eyes of the subject are on a common level. The focal length of the lens should be approximately six times the measurement of the image of the head to avoid abnormal perspective, and should be of sufficient speed to allow instantaneous exposure; a speed of *f*/3.5 or *f*/4.5 generally being quite satisfactory. The operator should use the eyes of the subject as a point of focus. They serve as the best example of the contrast necessary to focusing and are so situated as to afford sufficient depth of field. Identification photographs are $1\frac{1}{4}$ by $1\frac{1}{2}$ inches in size, with the image of the head measuring approximately 1 inch. In the trimmed photograph, the image of the head should be approximately $\frac{1}{16}$ inch from the top and midway between the sides of the picture space.

203. Illumination.—Flat lighting is used in identification photography, consisting of two lamps in efficient reflectors. A lamp is placed on each side and to the front of the subject so that the light is directed toward the sides of the face and evenly distributed. The lamps should be close enough to the subject to afford the use of a fast shutter speed and yet not so close as to be unbearable by the subject. They should be 4 feet apart and 6 inches higher than the camera lens. The placement above the lens is to avoid harsh reflections if the subject is wearing glasses, and to remove the light from his direct line of vision, thus reducing the possibility of a fixed stare. The illustration specifies lamp distances and positions relative to the subject and camera (fig. 52①).

204. Exposure.—The exposure time should be of short duration to reduce the effect of possible movement of the subject. A shutter speed of less than $\frac{1}{25}$ second is not recommended. With a fixed light intensity the exposure time necessary for correct exposure is governed by the speed of the film used and the nature of the subject. Either a panchromatic or orthochromatic color sensitivity is satisfactory but for the purpose of photographing a man's face an orthochromatic emulsion is especially recommended. Using two No. 1 photoflood lamps (as indicated in fig. 52①) with an equivalent wattage of 500 watts each, an exposure time of $\frac{1}{25}$ second at *f*/5.6 is satisfactory when using an emulsion of a Weston rating of 16 in artificial light. The subject should rest his eyes by closing them for a short period prior to exposure, to avoid blinking while the photograph is being made. The photographer should be prepared to "snap" the shutter when the eyes of the subject are open.

205. Official portraiture.—*a. General.*—Pictures of officers and personnel for special purposes are oftentimes required. They differ from identification pictures in that the subject is photographed to appear to advantage. The accompanying figure (fig. 52②) illustrating lighting technique will be helpful to the camera operator.

It is essential that a sufficient volume of light is available to permit instantaneous exposures of not more than 1/25 second at a suitable aperture. The general rules of placing the subject as outlined for

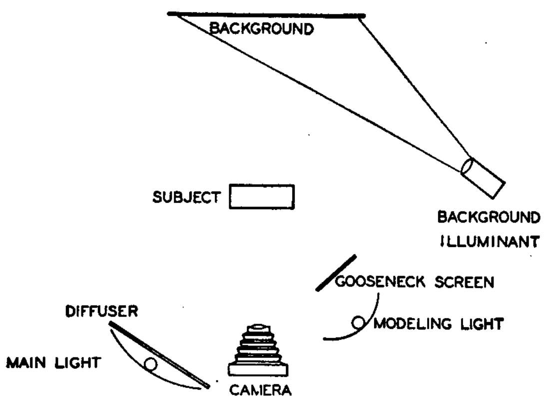


EXPOSURE TABLE

TYPE OF LAMPS	DISTANCE LAMPS TO SUBJECT	DISTANCE BETWEEN LAMPS	HEIGHT OF LAMPS	EXPOSURE FILM SPEED WESTON 16	EXPOSURE FILM SPEED WESTON 32	EXPOSURE FILM SPEED WESTON 64
2 #1 PHOTOFLOOD —OR 2 LAMPS OF 500 WATTS EA.	4 FT.	4 FT.	6 INCHES ABOVE EYE AND LENS-LEVEL	1/25 SEC. f/5.6	1/25 SEC. f/8.	1/50 SEC. f/8.

① Lighting for identification photographs.

FIGURE 52.



② Lighting for official portraits.

FIGURE 52—Continued.

identification photographs may be applied here with the exception of the subject's headgear which may or may not be worn, depending upon the orders as received by the photographer.

b. Illumination.—The modeling light is placed to the side of the subject and at a height sufficient to permit a 45° tilt of the lamp when directed toward the subject. The effectiveness of this light is augmented by the use of a head screen so adjusted as to reduce the light intensity as desired on different portions of the subject's face. The usual procedure is to reduce the light intensity between the temple and the ear and to equalize the illumination on both ears. The main light source is placed on the opposite side of the subject. Its main purpose is to soften any dark shadows and thus reduce harsh contrast. The illumination may be either diffuse or direct depending upon effects required by the particular subject. The distances at which these lights are placed from the subject are dependent upon the intensity of the illuminant and the particular portrayal of the subject as desired. The closer the modeling light is to the subject the greater its effect if properly governed by use of the screen as indicated in figure 52②. The background should be light if the subject is dark or medium, and light gray if the subject is fair. If a light or gray background is not available, the background may be illuminated with a bright spotlight. This will cause it to record light in the photograph. Rugged features, such as generally found among men and elderly people, require more modeling than will the features of a youthful and smooth countenance.

Section VIII

PHOTOGRAPHY OF MOVING OBJECTS

206. General.—Objects that must be photographed while in motion include soldiers on the march, combat vehicles, motorized equipment, airplanes, troops in action, sporting events, etc. (See fig. 53.)

a. In the photography of moving objects it is frequently desired to give the impression of motion and yet render the object with sufficient clarity as to be readily recognizable in nature and type. For example, in the case of an airplane in flight, it is desirable to use a shutter speed sufficiently short to stop the motion of the airplane but allow the blur of the propeller to give a sense of movement. Similarly, it is frequently desirable to let wheels of moving vehicles be slightly blurred to indicate that they were in motion at the moment of exposure.

b. In other cases it is necessary to show details of objects in motion, such as caterpillar treads, recoil mechanisms, truck springs, landing gear action, etc. This type of photography should render the object as sharp as possible. Certain types of subjects have moments of reduced movement as the moving part approaches center and the cameraman must be on the alert to make the exposure at the time when the probability of securing sharp detail is increased. It is sometimes helpful to swing the camera and follow a moving object in order to obtain sharp detail, even though blurring the background. Here again the impression of motion is given without sacrifice of detail. If, however, the action or motion of the vehicle is not essential to the photograph, then it can be secured better while the subject is motionless.

207. Factors to be considered.—*a. Speed.*—When the moving object is such that it is necessary to prevent blur or lack of definition in the image, the exposure must be sufficiently brief so that the effective movement of the object during exposure will not be apparent The speed at which the object is moving, insofar as it affects the taking of the picture, is in reality the speed at which the image of the object travels across the film. In considering the speed of the object, both the ground distance traveled and any movement within the object itself should be included. For example, in the case of a horse running, the movement of the horse's feet will be proportionately greater than the speed of the horse's body. It is generally advisable to calculate the exposure for the most rapidly moving part which often means shortening the exposure by about one-half that required for the whole object. This in turn must not be calculated to such an extreme that all sense of motion of the object will be lost as previously explained.

b. Angle of movement.—The image speed and therefore the permissible exposure time depends upon the speed of the subject and also the direction of its motion relative to the axis of the camera. A subject moving at a given speed directly across the field of view will require a shorter exposure than when at any other angle. When the direction of motion is at an angle of 45° to that of the camera, relative motion will be stopped by twice as long an exposure as that used for the same object traveling at 90°. Moreover, from a pictorial or compositional standpoint the 45° viewpoint is greatly preferred.

c. Distance of object from lens.—The distance of the subject from the camera is of importance principally as it affects the depth of field. Thus, in order to secure sufficient exposure, it is desirable to photograph from a greater distance if the diaphragm must be used at its maximum opening.

d. Focal length of lens.—The depth of field is governed by the focal length of the lens used from a given viewpoint or distance. In many instances enlargement in printing will be necessary to produce an image of the desired scale.

208. Calculating the shutter speed.—*a. Table of speeds.*—A table of approximate shutter speeds adaptable to various types of subjects is shown in figure 53 for use as a guide to exposure.

b. Cameraman's technique.—Success in the photography of moving objects depends upon skill in handling the camera. Unless the cameraman is thoroughly familiar with his instrument and can instantly set, reset, or adjust it in the brief time allowed while a moving object is rapidly approaching, it will be found that the object will have passed out of view before the exposure can be made. In the photography of moving objects the mind of the operator is usually occupied with making rapid decisions as to exposure and position. In fact, the operator usually will be constantly shifting his position in order to secure the most favorable one and at the same time adjusting the shutter and perhaps also the lens diaphragm to give the required exposure at the new position. It is good practice to select a point in the path of the approaching object and take sufficient time to focus very carefully on this point. If the point selected is near and the focus is desired for as large an area as possible around the point, the lens should be stopped down to the smallest diaphragm opening at which the exposure required can be made.

TABLE OF SHUTTER SPEEDS TO RECORD SUBJECTS IN MOTION			PROPER SHUTTER SPEEDS		
			MOTION TOWARD OR AWAY FROM CAMERA	MOTION AT ABOUT 45° ANGLE TO CAMERA	MOTION AT RIGHT ANGLES TO CAMERA
SUBJECTS IN MOTION	APPROXIMATE SPEED OF SUBJECT IN MILES PER HOUR	DISTANCE OF SUBJECT FROM CAMERA			
LANDSCAPES INCLUDING SLOWLY MOVING WATER		BEYOND 25 FEET	1/50 TO 1/100		
PEDESTRIANS, SLOW-MOVING ANIMALS CONSTRUCTION WORK, STREET TRAFFIC BOATING, TROOP MOVEMENTS	5–10	25 FT.	1/135	1/265	1/400
		50 FT.	1/65	1/135	1/200
		100 FT.	1/35	1/65	1/100
ATHLETICS, BASEBALL, YACHT RACES HORSE RACING, MOTOR BOATS SURF, DIVING, VIEWS FROM TRAINS	20–30	25 FT.	1/335	1/665	1/1000
		50 FT.	1/135	1/265	1/400
		100 FT.	1/65	1/135	1/200
AUTO RACES, MOTORCYCLES, AIRPLANES LANDING AIRPLANES, FAST TRAINS	60 AND OVER	25 FT.	1/500	1/1000	....
		50 FT.	1/335	1/665	1/1000
		100 FT.	1/135	1/265	1/400

FIGURE 53.—Table of shutter speeds for moving objects.

(1) The shutter speed to be used to confine the movement of the image on the plate to the desired amount can be computed mathematically. Ordinarily an image which does not have a movement greater than $\frac{1}{100}$ inch is considered to be sufficiently sharp. However, when it is known that the negative is to be enlarged many diameters it is necessary that the movement of the image be restricted to a smaller distance.

(2) The movement on the plate is greatest when the object being photographed is traveling at right angles to the lens axis. When the angle is 45° to the lens axis the movement is about two-thirds as great. Therefore, the exposure time can be increased 50 percent and the same amount of movement will result as when made at the

faster shutter speed with the object traveling at right angles to the lens axis.

When the object is moving directly toward or away from the lens there is respectively a slight increase or decrease in the size of the image. An exposure time three times as long as that which would be necessary when the object is traveling at right angles to the lens axis will restrict this change in size so that the movement (or displacement) will ordinarily not be greater than the specified allowable movement. To compute the shutter speed to be used in photographing moving objects it is customary to compute that which would be proper when the object is traveling at right angles to the lens axis. If the movement is 45° to the axis this exposure time is increased 50 percent. If the movement is parallel with the lens axis the first computed exposure can be increased three times.

(3) The following will illustrate how the exposure time is computed. It is desired to photograph a motorized vehicle in such a manner that the image will be 8 inches long and the movement of the image confined to $\frac{1}{100}$ inch. An object 30 feet long is traveling 60 miles per hour at an angle of 45° to the lens axis. To compute the exposure time, the distance from the lens to the object must first be determined. The proportion to use is $d : D :: F : A$.

d=length of image
D=length of object
F=focal length
A=distance from lens to object

Substituting known values:

$$8 : 360 :: 12 : A \text{ or } A=540 \text{ inches or } 45 \text{ feet}$$

Then:

$$\frac{\text{Distance in inches} \times \text{allowable movement}}{\text{Focal length} \times \text{speed in inches per second}} = \text{shutter speed}$$

Or substituting known values:

$$\frac{45 \times 12 \times \frac{1}{100}}{12 \times 1056} = \frac{1}{2346} \text{ or approximately } \tfrac{1}{2400} \text{ second}$$

which would be the correct exposure time when object was traveling at a 90° angle to lens axis. Traveling at 45° to the lens axis an exposure time 50 percent greater or $\frac{1}{1600}$ second would be correct.

(4) It is often realized that after the exposure time for making a photograph of a moving object has been calculated, it is impossible to use it. This may be because the calculated exposure is insufficient, or because the shutter is incapable of the calculated speed. To establish a practical exposure time, it is necessary to calculate an exposure time within the range of available shutter speeds. If a decrease of shutter speed is necessary to correct exposure, the camera must be moved to a greater distance from the object in order to keep the movement of the image on the plate within the desired limit. The increase in distance is directly proportional to the increase in exposure time. For instance, in the above example, at a distance of 45 feet an exposure of $\frac{1}{1600}$ second was correct. Consider that it was desired to make the exposure at $\frac{1}{1000}$ second, the distance from camera to subject would then be:

$$\frac{1}{1600} : \frac{1}{1000} :: 45 : X \text{ or } X = 72 \text{ feet}$$

The scale of the image decreases in direct proportion to the distance of the camera from the object. Consequently the image would be too small in the case just cited. The image may be enlarged by projection but consideration must be given to the fact that for each diameter of enlargement the effective movement on the plate is multiplied by two. In order to maintain a movement on the finished print of not more than $\frac{1}{100}$ of an inch, the cameraman must reduce the actual movement of the image on the focal plane. The movement allowable is determined by the times enlargement necessary in printing.

209. Focusing the image.—In the photography of moving subjects, it is practically impossible to keep the subject in focus, watch its approach, and trip the shutter at the critical moment. The faster the movement, the more difficult this becomes. To circumvent this difficulty, the usual practice is to prefocus an area on the ground that will be sufficient to include the required area of the subject. Allowance must also be made for the reaction time of the cameraman. Therefore the shutter control is operated at such a time that the subject will be in the area on which focused at the time the shutter opens and closes.

210. Sensitized material.—Ultra speed films having Weston ratings of 100 or more have greatly simplified the problem of the photographer in making fast action photographs. This type of film can well be used with all conditions of daylight and up to 1/200 of a second when using photoflash bulb illumination.

211. High-speed photography for technical studies.—For detailed study of rapidly moving pieces of equipment it is necessary to have completely sharp photographs. For this reason exposures of less than $1/10000$ of a second are sometimes used. Inasmuch as camera shutters are incapable of these speeds the light source itself is made intermittent creating an instantaneous flash. With such short exposures the light intensity must be extremely high in order to secure negatives of sufficient density. Gaseous discharge lamps and high voltage sparks are used to furnish light of extremely short duration. This type of photography is used in studying the stresses placed on aircraft structures, propeller torque, vibrations, landing-gear recoil, gun movements, and other engineering uses.

Section IX

FLASHLIGHT PHOTOGRAPHY

212. General.—Flashlight is a form of artificial light of a highly concentrated nature. It is used generally to obtain instantaneous exposures of objects with which other types of lighting would be impractical. Flashlight can be used as a unit of illumination or as an auxiliary to either artificial light or daylight. It is especially useful for making indoor pictures as it is easily controlled and is readily adaptable to produce any degree of contrast or softness.

213. Flashlight materials and equipment.—Flashlight can be produced by igniting a highly combustible powder in an open flash pan or by use of the photoflash lamp. Flash powder is used principally for night aerial photography and for large outdoor ground gatherings. Flash powder is seldom used for interiors because of the fire hazard, smoke, and dust. Inside the bulb of the photoflash lamp is a quantity of magnesium alloy which is explosive under certain conditions and capable of producing light. The explosive element is usually in the form of a fine wire or crumpled foil and may be ignited by electricity. Bulbs containing foil can be fired by contact with each other, one central bulb being fired electrically. Wire-filled bulbs cannot be fired by this method of contact. Photoflash bulbs are usually provided with some protection against bursting when fired, such as a coating of transparent medium both inside and out. Some bulbs have a safety color spot which changes color if there has been a leakage of air into the bulb. This change of color indicates that the bulb is not safe to use.

214. Synchro flash.—Synchronized flash guns are shutter opening devices that are either electrically or mechanically (spring) operated. In principle these guns are alike although the practical application of the several types may differ. When the switch is closed, contact is made which fires the bulb and operates the shutter-opening mechanism. Synchro flash may be used with between-the-lens or focal plane shutters. When using a flash with a focal plane shutter difficulty may be encountered in producing an even exposure over the entire plate. This is because the "peak" of the flash is of less duration than the time required for the shutter to act. It is necessary to use a bulb of an illuminating peak long enough to accommodate the shutter action.

215. Uses of synchro flash.—Synchronized flash equipment is desirable for most interiors and for exteriors under poor lighting conditions. Synchronized flash may be used to great advantage in filling in the shadows present under harsh exterior lighting and is frequency used for personnel photographs made under brilliant sunlight. Its application to equipment photography under like conditions is obvious.

216. Reflectors.—*a.* Some reflectors are designed to concentrate more light in the middle portion of the covering area. Such reflectors should never be used when flood light illumination is necessary. The efficiency of any parabolic or spherical reflector depends upon five very important factors: Position of the bulb, distance of bulb from center of reflector, size of bulb in relation to reflector, the curve of the reflector, and polish of the reflector.

b. The position of the bulb in the reflector determines the direction of the projected rays. The light-producing area of the bulb should be centered with the parabolic curve so that the light rays will be projected straight ahead. Some reflectors have an adjustable device to assist in accomplishing this purpose which, however, is only partly effective, being also dependent on the size of the bulb.

c. The distance of the bulb from the center of the reflector has a direct bearing on the evenness of the illumination. For example, if it is too far forward, the light rays will cross giving uneven illumination and a "hot spot" at the point of crossing.

d. The size of the bulb or light source in relation to the reflective area is also important. A reflector should be designed to accommodate a light bulb of certain dimensions. If a different size bulb is used than that for which the reflector is made, there will be a proportional loss of efficiency.

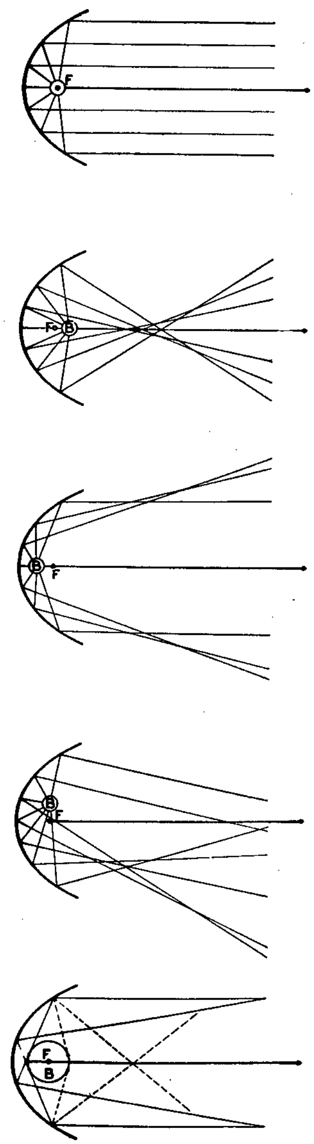


FIGURE 54.—Reflector efficiency.

e. The shape of the spherical or parabolic curve governs the "spread" of the light rays projected. For example, a reflector that is shaped more like a cone than a dish will project a narrow and more concentrated beam. A dish-shaped reflector will spread the light more in the nature of floodlighting or broad illumination. Some reflectors are provided with an auxiliary ring of metal with a diffusing surface. This ring covers approximately half the bright or polished surface and serves to diffuse the outer ring of light and increase the angle of spread. The various features of the action of light in relation to reflectors are illustrated in figure 54.

217. Photoflash bulbs.—Photoflash bulbs, or lamps, may be procured in many different sizes from the golf-ball size to the large high intensity lamps for photographing large groups and areas. A blue-coated lamp is also available for use in color photography.

218. Exposure.—*a.* Flash exposures, whether lamp or powder, are not calculated in the same way as other exposures. It is obviously impossible to use a light meter. Other than the usual exposure factors, exposure is dependent upon the size of the flash used, the photographic characteristics of the flash, and the operating distance from the subject. To ascertain the correct exposure the amount of light emitted by the flash and its actinic or photographic qualities must be known. This established, the exposure is computed by consideration of the operating distance and the exposure requirements of the subject itself. Exposure tables furnished by the manufacturer of flash bulbs are of great value to the cameraman and should be used whenever bulbs of unknown intensity and spectral analysis are used.

b. As an emergency test of synchronization of flash and shutter the cameraman may fire a lamp and by looking through the lens as the shutter opens, ascertain if the flash is evident. If the flash is plainly in evidence at the highest shutter speed available the synchronization is in proper sequence.

SECTION X

EXPOSURE

Paragraph

219. Definition.—A photographic exposure is the subjection of a sensitized emulsion to light. The amount of exposure a sensitized material can receive is dependent upon the actinic intensity of the light and the duration of time the light is allowed to act. Intensity times the time, therefore, equals the exposure ($S \times T = E$).

220. Factors of exposure.—*a.* In calculating exposure the following factors should be considered:

(1) Shutter speed and lens aperature.
(2) Intensity of light source.
(3) Speed of the emulsion.
(4) Brightness range of the subject.
(5) Color of illumination.
(6) Development.

b. Shutter speed.—(1) The shutter speed is the duration of time that light is allowed to pass through the lens and is dependent upon the intensity of the light source and the size of the lens aperture. For any given set of illumination conditions and film speed, the shutter speed varies with the lens aperture. The larger the aperture the faster the shutter speed.

(2) The lens aperature is the effective area of the lens through which light is allowed to pass during the time the shutter is open. The faster the shutter speed, the larger the effective aperature for a given exposure.

c. Intensity of the light source.—The intensity of light varies inversely with the square of the distance from its source. Light reflected from an object varies in this same ratio. The cameraman is concerned with the light which actually reaches the focal plane when he is determining the exposure necessary.

d. Emulsion speed.—The faster the film in use, the shorter will be the exposure necessary to record the desired image. The exposure, then varies inversely as the speed of the emulsion.

e. Brightness range of the subject.—The range of brightness in the subject to be photographed is a direct factor in determining exposure. A subject of short brightness range will require less exposure then varies inversely as the speed of the emulsion.

f. Color of illumination.—The exposure is directly dependent upon the color of light in the illumination and the color sensitivity of the film being used. For artificial light exposures, a film which has a high sensitivity to red should be used because the illumination predominates in the longer wavelength region of visible light. Artificial light exposures are longer than average daylight exposures due to deficiency of highly actinic blue light. Exposures in late afternoon would also be longer than in early morning and midday because the light from the sun would predominate in red.

g. Development.—The extent to which a developer will develop the shadow detail of a negative varies with different developers. This variation is so great that manufacturers of sensitized emulsions state a speed rating for an emulsion based on a definite degree of development in a specified developer. This speed rating is used in determining correct exposure and will vary if other than the recommended developer is used.

221. Calculating the exposure.—There are three methods in general use for computing exposure; the use of exposure meters, the key stop system, and the application of exposure tables. The computing of exposures by the use of a photo-electric meter is generally conceded to be the most accurate method as the element of human error is more likely to occur when using other systems.

222. Photo-electric exposure meter.—A photo-electric exposure meter is an instrument by which the intensity of the light may be measured and the correct exposure computed. The meter consists of three main parts as follows:

a. A light-sensitive cell which, when energized by light, forms an electric current. The amount of this current is proportional to the intensity of the light received by the cell.

b. A device which measures the electrical current formed and has a numerically graduated scale to indicate the amount of light incident on the cell.

c. A movable scale for computing the exposure. The meter should never be subjected to heat greater than 140° F. in order to avoid deterioration of the sensitive coating on the cell which would change the calibration.

223. Visual extinction meter.—The visual extinction meter operates on the principle of light transmission through a numbered or lettered disk enclosed in the body of the meter. The clarity of the characters on the disk appearing in the graduated illumination indicates the light value. After the light value has been determined, the exposure time is computed by means of a mechanical scale in which the speed of the film and the lens aperture is taken into consideration.

224. Key stop system.—*a. General.*—When an exposure meter is not available, the exposure may be calculated by a system known as the kep stop which is, in effect, a means of employing the camera as a visual extinction meter.

b. Method.—To determine the exposure by this system, a camera with a focusing screen is necessary. The camera is set up and properly adjusted, with the lens set at its greatest aperature. The photographer next views the subject directly to obtain a mental impression of the illumination. When this is accomplished, the image on the focusing screen is viewed, with all extraneous light excluded. The lens is then stopped down until the intensity of the illumination in the image is equivalent to the mental impression of the subject. The aperture reached is called the kep stop. The exposure time at this aperture will vary with the film speed and is approximately equal to the reciprocal of the Weston speed rating. For example, a film with a Weston speed of 24 would have a key stop exposure time of $\frac{1}{25}$ of a second, Weston speed 50 would give $\frac{1}{50}$ of a second, etc. If the lens must be stopped down farther than the key stop to obtain more depth of field, or opened up to obtain faster shutter speed, the exposure must be computed accordingly.

225. Tables and guides.—*a.* The purpose of the exposure table is to facilitate the finding of the correct exposure in terms of shutter speed and lens aperture for different types of subjects according to the speed rating of the film used and the prevailing light condition, either daylight or artificial. The table shows how to determine exposures that are correct within the latitude of the film used, for different types of subjects, when the exposed film is processed in the manner recommended. An exposure table is shown in figure 55. While exposure tables and guides do not measure actual light values, it will be found that by exercising ordinary care and judgment in their use, exposures of sufficient accuracy may be readily determined.

Lens apertures at 1/25 second

	Brilliant subjects	Bright subjects	Average subjects	Shaded subjects
Bright sun	F/22	F/16	F/11	F/8
Hazy sun	F/16	F/11	F/8	F/5. 6
Cloudy-bright	F/11	F/8	F/5. 6	F/4
Dull	F/8	F/5. 6	F/4	F/2. 8

FIGURE 55.—Daylight exposure table.

b. An exposure table that is provided with a movable part which is adjustable for different types of subjects under varying light conditions is referred to as an exposure guide. The speed of the film being used is considered in the calibration of the guide. Usually the part of the outdoor guide referring to the light condition is divided into four sections: bright sun, hazy sun, cloudy-bright, and dull. The part of the guide referring to the subject is divided into four classifications: brilliant, bright, average, and shaded. By connecting the movable part of the guide indicating the light condition with the type of subject to be photographed, the shutter speeds and corresponding *f* number lens openings to give the correct exposure for a particular film are automatically shown. (See fig. 56.)

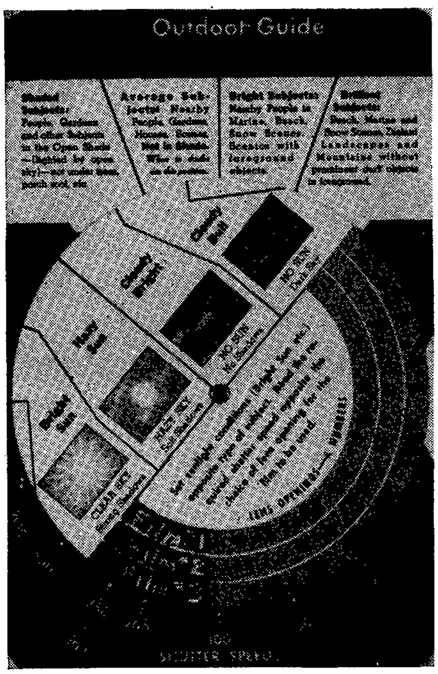


FIGURE 56.—Daylight exposure guide.

c. An exposure guide for artificial light exposures usually has definite light conditions and shutter speeds on a fixed scale. On a movable scale, an arrow is marked. This arrow points to the light condition. On the lower part of the scale the lens aperture is indicated for definite films depending upon the emulsion speed. Light conditions are given for definite types and numbers of lamps at various distances. (See fig. 57.) It is advisable for the cameraman to maintain a record of

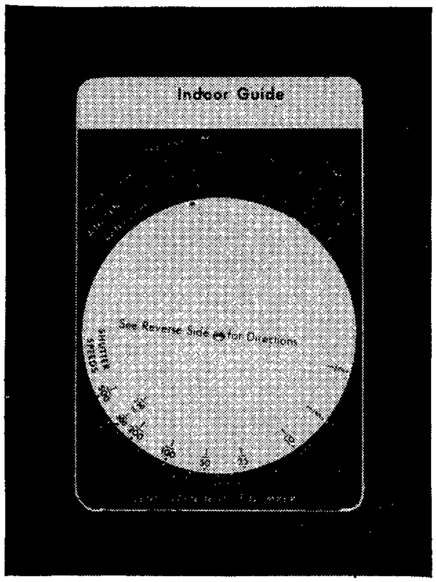


FIGURE 57.—Artificial light exposure guide.

exposures. This will serve as a guide for future use of the data set forth by the exposure guide or table and will develop a sense of exposure judgment.

CHAPTER 9

NEGATIVE MAKING

SECTION I

GENERAL

226. Importance.—Negative making is the most important step in the production of a photograph. The first requirement is that the sensitized material be correctly exposed and afterward that it be developed properly. The negative, therefore, is the foundation of the photograph and when a good negative has been produced, the successful completion of the photograph is more than half accomplished. From a negative which has been thus produced, it is possible to make any desired number of prints with comparatively little difficulty.

SECTION II

EXPOSURE

227. General.—The first step in the production of a negative is the exposure. In any photograph, there is a representation of the form of an object and of the effect of the light falling upon it. This effect is called "light and shade." Correct reproduction of the outlines of the photographic image depends upon the quality of the lens. In this section, consideration will be given to the proper representation of the effect of the light falling upon the subject, which is the basic problem involved in negative making.

228. Light intensities.—Any subject that might be photographed is composed of areas which reflect different intensities of light. The areas which reflect much light are called "highlights" while those which reflect little light are called "shadows." Other areas which reflect more light than the shadows but less than the highlights are called "halftones." A photograph, to represent a subject properly, must be composed of areas which will reflect amounts of light proportionate to the corresponding areas of the original subject. In the photograph of a house (fig. 58) the pipes at the top of the chimney and the white stucco between the paneling of the gables are the lightest portions of the photograph and are, therefore, the most prominent highlights. The projecting wing of the house, by cutting off the direct rays of the sun, forms a heavy shadow on part of the roof and part of the garage. This is one of the darkest shadows of the photograph. The lighter areas of the lawn are neither dark nor light but are halftones. There are many shadows, highlights, and halftones in the photograph other than those pointed out. A study of the photograph will also disclose that there are a large number of variations between the highlights and the halftones and between the halftones and the shadows. The range of shades from white to black is long. The intermediate tones between the highlights, halftones, and shadows are called gradations. Many subjects contain an innumerable number of gradations of light intensities. These fine gradations must be recorded in the negative in such manner that they will be reproduced in a print made from the negative. Such a negative is said to have good gradation. When a negative of an average subject has a good gradation, it is proof that the negative was properly made, as good gradation can be obtained only when the exposure and development have been correct.

229. Tones.—Perhaps a clearer idea of what is meant by a "tone" can be obtained from the study of a simple subject. In the photograph of a house (fig. 58) there are many tones. However, in the picture of an eight-sided block (not considering the top of the block) (fig. 59) there are only four tones in the range from lightness to darkness. They are:

a. The side of the block directly facing the light, which is the brightest side.

FIGURE 58.—Light intensities in a normal subject.

b. The side next to the brightest which is turned slightly away from the light and is, therefore, not so bright as the first side.

c. The side opposite the direction of the light, which is, therefore, the darkest side.

d. The black background.

230. Reproduction of tones.—In order to show how the tones of the subject are reproduced, there has been included in figure 60 a cross-section view of the negative reproduced above it. From a study of this negative of the block, it will be observed that during the exposure the light reflected from the brightest side of the block was so strong that the silver halide grains were exposed through the entire depth of the emulsion. However, the light reflected from the other sides of the block was weaker and its effect on the emulsion not so great, that is, light reflected from the front of the block affected only the grains lying in the upper half of the emulsion; light from the shadow side affected those grains lying near the surface; while that from the background was insufficient to affect any of the silver halide grains. The effect of the light on the emulsion was in direct proportion to its strength, and when the negative was developed, only the exposed or affected grains were changed into grains of metallic silver as the figure shows. The formation of a usable image requires that a certain number of silver halide grains be acted upon by the light, not too many and not too few, but just the proper number. The length of time that the image is allowed to be projected by the lens on the film while it is in position in the camera (the exposure) controls the number of silver grains which must be affected by the light to produce the required negative image. The exposure must be just long enough to affect the proper number of silver halide grains.

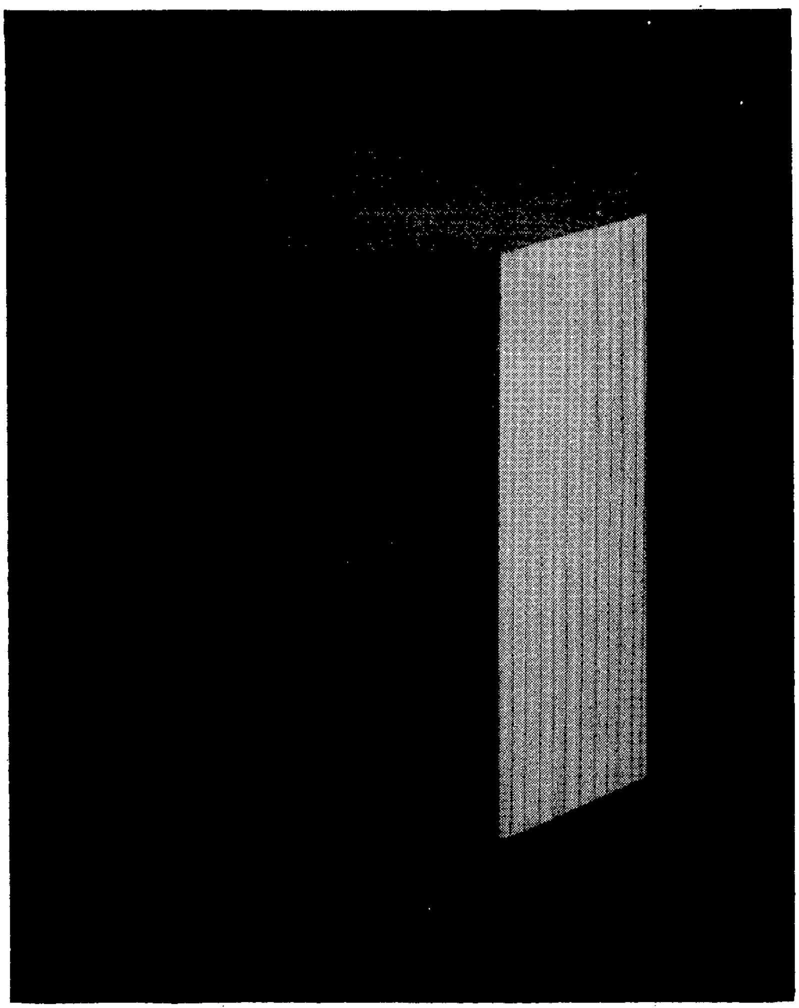


FIGURE 59.—Highlight, halftone, and shadow.

These light-affected grains are reduced during development to fine particles of black metallic silver which, when viewed through a high-powered microscope, resemble infinitesimal lumps of coke as shown in the photomicrographs (fig. 62).

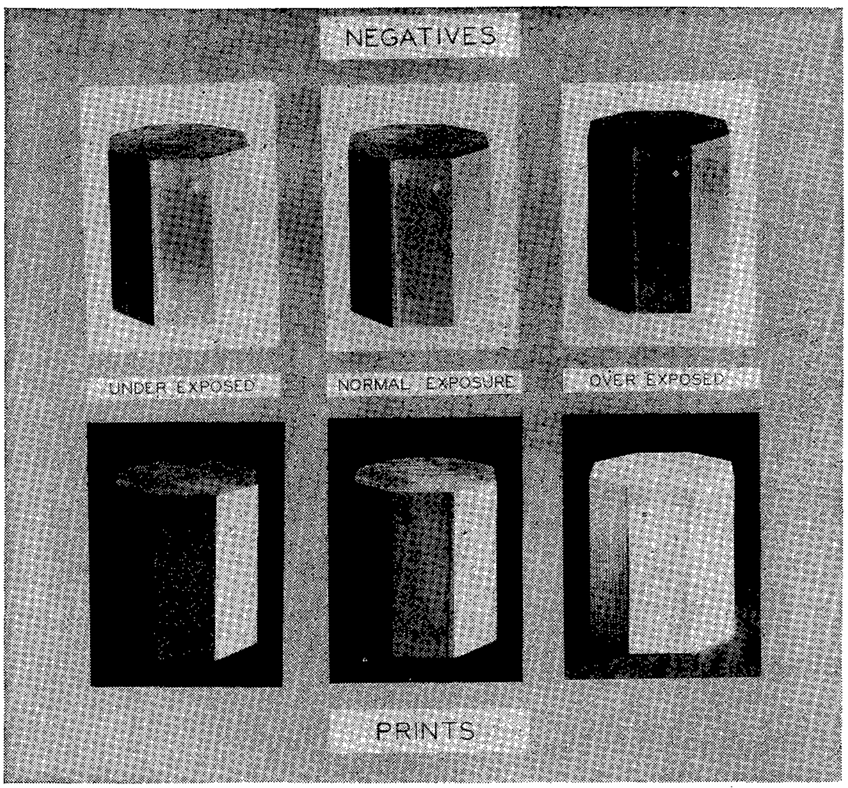


FIGURE 60.—Underexposure, overexposure, and normal exposure.

231. Effect of exposure on tone.—The image in the negative consists of deposits of minute black silver grains scattered throughout the emulsion. There are deposits of these grains of various depths or densities corresponding to the intensities of the light as reflected by the different parts of the subject photographed. If the amount of the exposure has been insufficient, these deposits will not be dense enough; if the exposure has been too great, the deposits will be too thick and opaque and the tones in the subject will not be correctly reproduced. In this respect photographing an object differs greatly from viewing an object. When looking at the actual block with the light falling upon it in the same way as shown in

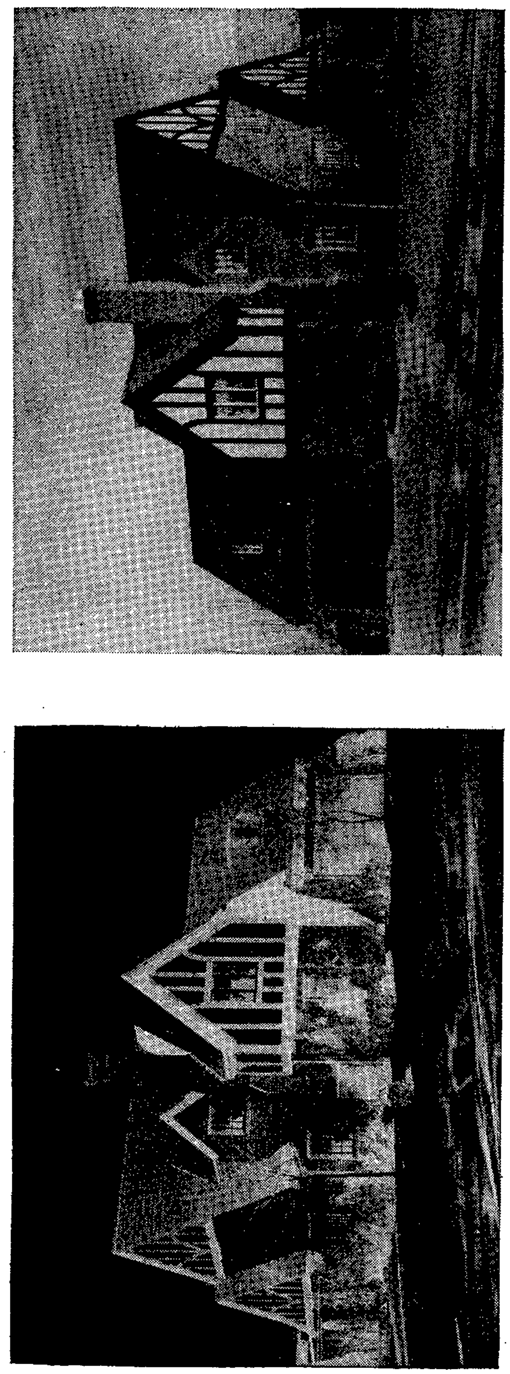


FIGURE 61.—An ideal negative and print.

figure 60, the four tones or shades are easily seen, and just as long as the block is gazed upon, it will appear exactly as it is in the picture. The camera would see the block in this manner after a time, but then only for a little while, at the expiration of which it would rapidly begin to see it quite differently. The amount of time therefore, that the camera is allowed to see the subject during the length of the exposure is vital to the correct reproduction of the tones of the subject. This will be apparent from a study of figure 60 in which are shown a series of negatives which are respectively underexposed, normally exposed, and overexposed. In the lower half of the illustration is shown a print made from each negative. It will be noted that the highlight in the photograph made from the underexposed negative is not clear and bright as it should be, that the halftone is too dark, and that the shadow is dense and shows no detail. In the photograph made from the correctly exposed negative, the tones are such that a true representation of the block is secured. In the photographs made from the overexposed negative, it is evident that the highlight is much brighter than it should be, that the halftone is really a highlight, and that the shadow is almost a halftone; also, there is more detail in the shadow than is necessary to the true reproduction.

232. The perfect negative.—*a.* A perfect negative is one from which, with a minimum effort, a print which portrays the subject in the desired manner can be secured. To produce such a print the densities of the negative must correspond to the different brightnesses of the subject.

b. Figure 61 shows what is considered a perfect negative and a print made from the negative. Comparison of the negative and print will show how the tones are reversed and how each gradation of tone in the negative is reproduced as equal gradations in the print.

c. In figure 62, the three small circles on the negative inclose minute sections of the emulsion which are respectively a highlight, a halftone, and a shadow. The photomicrographs show the relative number of silver grains in these different densities of the negatives.

d. If it were possible to view a complete cross section of a negative under a microscope, the deposits of silver grains would appear not unlike a range of mountains, the highlights appearing as peaks, the shadow portions forming valleys, and the intermediate tones forming intermediate heights. Figure 62 shows how the grains of silver lie in the emulsion of a negative.

233. Effect of exposure on density.—*a. General.*—By the density of a negative is meant the extent of the silver deposits in it which constitute the image. Density controls opaqueness or blackness and

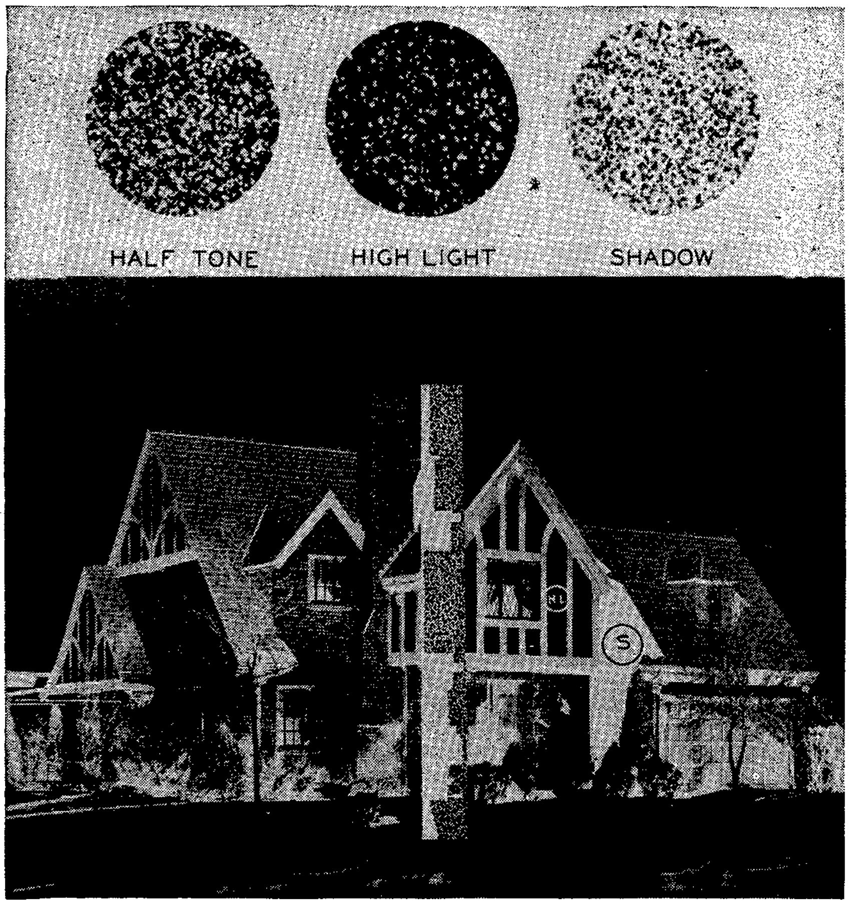


FIGURE 62.—Silver grains in various densities.

capacity for stopping or regulating the light in printing. The extent to which the quantity of silver deposited in a negative determines the amount of light which passes through the negative can be explained as follows: The deposit of silver in a certain area of a negative is such that 30 percent of the light is transmitted. In the corresponding area of another negative which had more exposure, the amount of silver deposited is twice as much. Imagine that this second deposit lies in two layers, each equal to the layer in the first negative. The first of these two layers will pass 30 percent of the light. The second layer will pass 30 percent of the 30 percent transmitted by the first layer. This will be 9 percent and not 15 percent, which amount might seem logical at first consideration. It is most important in making negatives to realize that a slight difference in the density of any portion of a negative makes a decided difference in the amount of light that will be transmitted through this portion of the negative.

b. Correct density.—The amount of silver constituting the image determines the density of a negative. When the amount is small the negative is called a thin negative, while when the amount is great, the negative is said to be dense. Either a thin or a dense negative may have any degree of contrast. However, negatives of nearly normal density are easier to judge for printing and are generally more satisfactory.

234. Densities with increased exposure.—*a.* The action of the exposure on the photographic emulsion used in negative making has been scientifically studied. Under the same conditions of light and with the same kind of plate and developer, a series of photographs were made in which the exposure for each succeeding plate was double the amount given to the preceding plate. These plates were developed for the same length of time and with the same kind of developer, and the amount of the silver deposit in each was measured. The result of this work can be graphically represented by a "staircase" (fig. 63), the steps of which, although continuous, are found not to be uniform and alike, but composed of three kinds, as follows:

(1) Those in which the rise of each step gradually increased (period of underexposure).

(2) Those in which the rise of each step did not increase but remained equal to the tread of the step (period of correct exposure).

(3) Those in which the rise of each step gradually decreased (period of overexposure).

b. In other words, during the period of underexposure, the density of the negative gradually increased in proportion to the increase of exposure; during the period of correct exposure, the increase in density was in exact proportion to the increase of exposure; and during the period of overexposure, the increase in density gradually decreased as the exposure was increased. From this it will be seen that unless sufficient exposure is given, sufficient density will not be obtained; and on the other hand if too much exposure is given, the maximum amount of density will be obtained and at the same time the proper degree of contrast will be lost. It is only by correct exposure followed by correct development that proper density and a proper degree of contrast are obtained, and the correctness of such procedure has been verified by scientific investigations.

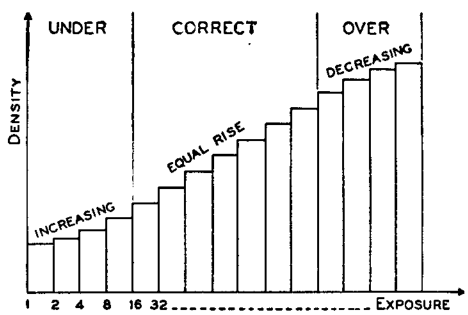


FIGURE 63.—Density exposure relation.

SECTION III

DEVELOPMENT

235. General.—The first of the two principal factors involved in negative making is exposure and the second is development. Since the different intensities of light form the latent image in the emulsion, the purpose of development is to change the latent image into a visible and usuable image.

236. Degree of development.—The degree of development depends upon the type of developer, its dilution and temperature, the amount of agitation given during development, and the length of time the emulsion is allowed to remain in the solution. When only one type of developer is under consideration, the first of these factors is usually constant, which makes the time of development the most important.

237. Temperature coefficients of developing solutions.—*a.* An image in an emulsion will be developed in a definite time when the developing solution is used at a certain temperature. The developing time varies inversely with the temperature. A temperature coefficient is a numerical value which can be used to compute the developing time to secure equivalent results when the solution is used at different temperatures.

b. Temperature coefficients are based solely on the type of reducing agent used in the developing solution. The temperature coefficient for any developing agent is constant, being little affected by the other ingredients of the developing solution or by the amount the solution is diluted. However, the temperature coefficient does vary slightly with the amount of potassium bromide in the solution and it varies slightly with different emulsions.

c. Temperature coefficients of developers can be secured from tables, direction sheets for using developers, or determined by tests. They are usually based on differences in temperatures of 10° F., but can be interpolated for temperatures between these readings. The following are the temperature coefficients for several commonly used developing agents based on 10° variations from standard temperature.

Metol	1.3
Hydroquinone	2.5
Metol-hydroquinone	1.9
Pyrogallic acid	1.9

d. An example of the application of temperature coefficients is: The developing time for a developer used at a temperature of 70° F. is 1 minute. When used at 80° F., the developing time will be 60 divided by 1.9 or 32 seconds. When the solution is used at 60° F., the developing time will be 1.8 times 60 or 1 minute, 54 seconds.

238. Development in relation to exposure.—The exposed film may be underexposed, correctly exposed, or overexposed; and development in relation to each of these three kinds of exposures may be for the proper length of time, or less than, or more than, the proper length of time. The nine different results thus obtained furnish a comprehensive study of both the factors entering into negative making, namely, exposure and development.

239. Contrast.—When an exposed film, being developed, is examined soon after the action of the developer has become apparent, it will be found that the difference in density between the heaviest and thinnest part is not great. However, after development progresses this difference continues to grow, and as development is nearing completion, the difference between the densest portion of the negative and the less dense portion will be very much greater than it was at the beginning of development. This difference is called contrast. When it is excessive, the negative is termed "hard" or "contrasty," and when it is insufficient, the negative is called "flat," "soft," or "lacking in contrast." When development is prolonged beyond the point where the desired contrast is achieved, contrast will continue to build up until it becomes excessive. A print from a negative that lacks sufficient contrast resembles one from an underexposed negative in that both photographs appear dull and fail to show the natural graduation from highlights to shadows. In a print from a negative that is too contrasty, there is an equally unnatural rendering of the subject in that the highlights are too bright and strong in comparison with the halftones and shadows, and the result is a harsh representation of the subject.

To sum up the contents of the last few paragraphs, it should be remembered that the amount of detail in the shadow portions of the negative is regulated by the length of exposure; that although the degree of normal contrast in a negative is exactly fixed by the nature of the subject, the actual contrast produced in a negative thereof is regulated by the degree of development so that the actual contrast may be insufficient because of lack of development or it may be excessive because of overdevelopment. It should also be remembered that density is the result of exposure plus development. A study of the chart describing the characteristics of the nine representative negatives, paragraph 241, and figure 65 will assist in understanding the effects of exposure and development in negative making.

240. Characteristic curves.—Figure 64 shows the characteristic curves which result when a negative is developed for 8 minutes and when developed for 12 minutes. From the curve, it is seen that the gamma of the negative developed 12 minutes will be higher than that of the one developed 8 minutes.

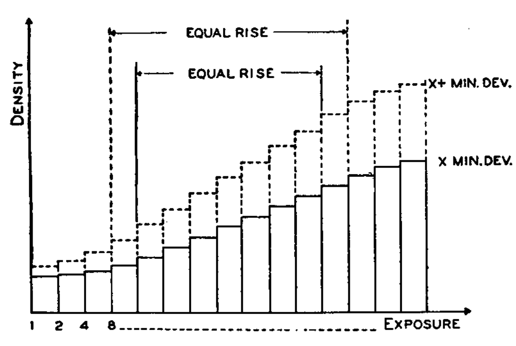


FIGURE 64.—Time-gamma comparison.

241. The nine representative negatives.—*a. General.*—The exposure of any negative may have been insufficient, correct, or too great. Similarly, the amount of development may have been insufficient, correct, or too much. Therefore, any developed negative can be classified as to exposure and development into one of nine types. Figure 65 shows these types of negatives. In making the illustration one set of three negatives was purposely underexposed, another was correctly exposed, and a third set was considerably overexposed. One negative from each set was developed for one-half the normal time, another negative from each set was given normal development, while the remaining three negatives were developed for double the normal developing time. Characteristics of the individual negatives are tabulated below.

	Underdeveloped	Normally developed	Overdeveloped
Underexposed			
Detail	Insufficient	Insufficient	Insufficient.
Density	Insufficient	Slightly lacking	Slightly lacking.
Contrast	Insufficient	Normal	Too much.
Normally exposed			
Detail	Slightly lacking	Correct	Correct.
Density	Slightly lacking	Correct	Too much.
Contrast	Insufficient	Correct	Too much.
Overexposed			
Detail	Too much	Too much	Too much in shadows and halftones. Highlights blocked.
Density	Correct or too much.	Too great	Decidedly too much.
Contrast	Insufficient	Too great	Too great.

b. Exposure.—Upon studying figure 65, it is seen that it is impossible to secure shadow detail in an underexposed negative even when the negative is overdeveloped. Also that there is a surplus of shadow detail in an overexposed negative even when the negative is underdeveloped. From these observations, it can be correctly assumed that the exposure forms the image in the emulsion while development brings out the image.

c. Contrast.—The degree of contrast in a negative depends upon how long the negative was developed. Figure 65 shows that the contrast of all the underdeveloped negatives is insufficient and that of all the overdeveloped negatives is too great.

d. Density.—The density of a negative is dependent upon both exposure and development. However, figure 65 shows that a badly underexposed negative will have insufficient density even though it

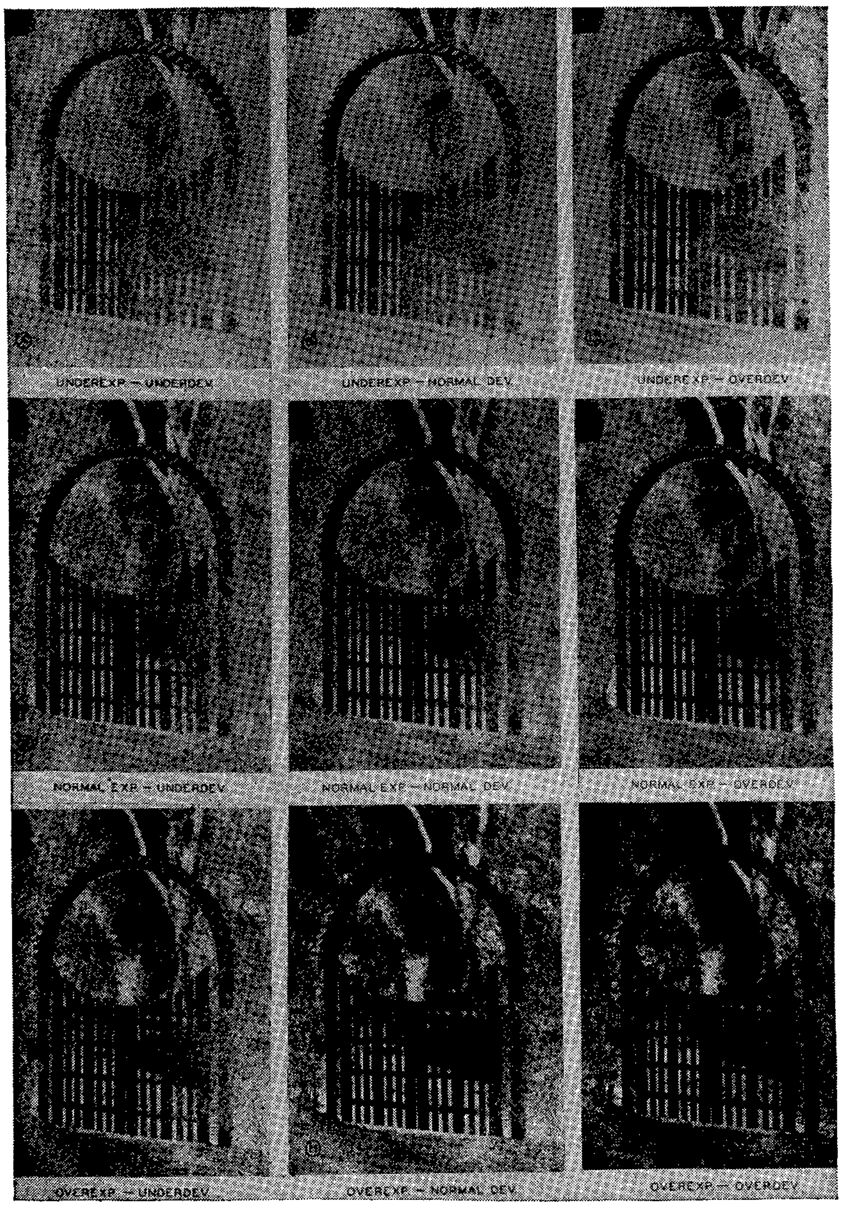


FIGURE 65.—Nine representative negatives.

be decidedly overdeveloped. Also, that an overexposed negative will likely have sufficient or even excessive density although the development was insufficient, and that an overexposed negative which has been normally developed is quite dense, while if overdeveloped, it will be excessively dense. In fact, it is impossible to secure an exceedingly dense negative unless it has been decidedly overexposed and when the density of a negative is too great it is most often the result of overexposure and not because of overdevelopment.

e. Importance of proper classification.—Too much emphasis cannot be placed on the importance of learning to classify negatives correctly as to exposure and development. The exposure and development of a negative are seldom exactly correct. In fact, the latitude of emulsions is such that it is of little importance if the exposure and development is not exactly correct, but it is of greatest importance that the photographer be able to recognize in a negative any variation from correct exposure and development so he can make correct changes in the ensuing negatives. If he is unable to recognize deficiencies in negatives, he will be inclined to make increasingly greater errors in exposure and development.

242. Time and temperature development.—*a.* The time and temperature method is based on the fact that a developing solution at a definite temperature will develop a given negative to a definite contrast (gamma) in a given time. This time will vary for different types of emulsions.

b. The recommended temperature for most developing solutions is 65° F. Best results are obtained at this temperature, but it is sometimes necessary to use developing solutions at a lower or a higher temperature. Most developers will function satisfactorily at a temperature as low as 55° F. and as high as 80° F. A few developers, known as tropical developers, can be used at higher temperatures.

c. The developing time to use at different temperatures in order to secure equivalent results can be computed by using the temperature coefficient of the developing solution or from time-gamma temperature charts.

d. A time-gamma temperature chart is a chart which shows the developing time necessary to secure the desired gamma or, conversely, the gamma which will result at different developing times at different temperatures. A separate chart is generally used for each different developer and emulsion. A chart may have a curve which is characteristic of only one type film or it may contain curves for several types. Figure 66 shows a typical chart. This chart shows the minutes of development necessary to obtain a gamma of 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, and 1.1 at any temperature between 55° and 90° F. This chart is for a standard fast panchromatic film when developed in a certain developing solution. The times given are for intermittent agitation of the solution. If constant agitation is used, the developing time can be reduced. Intermittent agitation is considered as agitating the emulsion at approximately equal intermissions 10 times during the time the emulsion is being developed. Constant agitation means continual agitation. This is usually secured by mechanical means when developing in tanks, or by constant rocking of the tray in tray development.

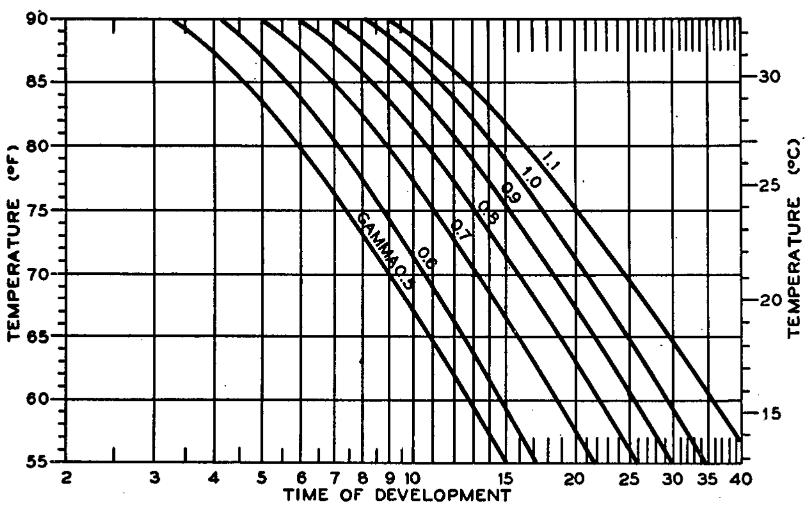


FIGURE 66.—Time-gamma temperature chart.

SECTION IV

MECHANICS OF DEVELOPMENT

243. Methods.—*a.* Cut film negatives are developed either in trays or in tanks. The tank system of development is the best method, especially when there are large quantities of negatives.

b. Short lengths of roll film can be developed in trays, suspended in tanks, or wound in reels having spiral grooves and developed in tanks. Aerial film is usually developed in a tank, being reeled from one spool to another by an electric motor during development.

244. Marking films for identification.—It is sometimes necessary to mark exposed films before development so that the developed negative can be identified. Ordinarily, film holders are numbered and notes made of any information pertaining to specific film numbers. Some film holders have a stenciled number in the corner which is imprinted on the film during exposure. This number coincides with the number on the exterior of the holder. When the number is not placed on the film during exposure, films can be marked by the following methods:

a. Placing identifying mark on the edge of a definite corner by placing the negative emulsion upon a rigid support and marking by means of a blunt pointed pencil having a lead of medium hardness or by means of a stylus.

b. Using ticket punch. When a large number of films must be identified, the punch marks can be in code or several punches making different shaped holes can be used.

c. It is somewhat difficult to use any of the above methods in absolute darkness, as it is difficult to confine the markings to the edge of the film. When large numbers of films are to be marked, it is advisable to cut a corner from a metal shield the same size as the negative. This can be used as a guard and guide. Films should be marked in the corner next to the notches. This facilitates locating the identifying marks on the negative.

245. Developing in trays.—*a. Types of trays.*—Stainless steel trays are generally used for all the solutions used in tray development although enameled steel, rubber, or glass trays may be used.

(1) The best practice is to use trays only slightly larger than the negative. This prevents the disarrangement of negatives. There is more danger of scratches when films lie in the tray in a haphazard manner.

(2) The tray for rinsing need be only slightly larger than the negative. The tray for the fixing bath should be at least twice as large as the one used for the developer.

(3) If a safelight is used, the tray for the developer should be placed about 30 inches from the safelight, the tray for the rinse bath to its right, and the tray for the fixing bath to the extreme right. The trays should be about 4 inches apart to prevent splashing of one solution into another.

b. Mixing solutions.—The fixing solution should be mixed first, then the rinse bath. The developing solution should be mixed last.

c. Mixing the developing solution.—The developing solution may have been mixed at using strength in which case it is only necessary to measure out and bring to the correct temperature the desired amount of solution. If the stock solution of developer must be diluted for use, the proper amount of water should be measured of the same temperature as that to be used for the developing solution. The diluted solution should be stirred to assure uniform density and temperature after which the temperature is verified by a thermometer.

d. Retaining temperature.—It is extremely important that the temperature of the solution remain constant while it is being used. Any change in temperature must be anticipated and necessary arrangements made to keep it uniform. Methods that can be used for this purpose are suggested in chapter 3.

e. Handling films in the developer.—(1) As six 8- by 10-inch films are the most that should be developed together in a tray, the method used to develop this number is as follows:

(*a*) Have all solutions ready, place film holders in a systematic arrangement, set timer for proper developing time, and turn out lights.

(*b*) Remove films from holders, placing them in a neat pile, emulsion down, on a clean surface. Place film, emulsion up, in left hand in a fan-like arrangement. Start timer. With right hand, slide first film, emulsion up, in the solution. Rock tray once or twice. In about 5 seconds, place the second film in the solution by pulling it, emulsion up, from left to right through the solution. Care must be exercised not to damage emulsion of film underneath. Pull the first film out of the solution, permitting the edge of the top film to squeeze lightly the solution from the emulsion of the bottom film. The first film is placed back in the solution in the same manner as the second film. The process is then repeated, which places the first film again at the bottom. This operation, while seemingly complicated, will not occupy 5 seconds time. Five seconds after the second film is placed in the solution the third film should be added in the same manner as the second. The operation is repeated, changing the positions of previously inserted films each time a new one is added, taking pains that when the sixth film is added, the position of each film (according to its number) is known.

(*c*) When all the films are in the solution, each film should be shifted from the bottom to the top of the pile. After they have been in the solution for about 2 minutes, it is permissible to wait about 20 or 30 seconds between changes. Care must be exercised not to grasp a film in the same spot each time its position is shifted as the heat of the fingers may cause stains or melt the emulsion in the spot which is touched. Also about midway of the developing time the tray should be turned halfway around. Then the films will be handled by their opposite sides.

(*d*) When the timer rings (or the developing time has passed) the first negative is removed from the developer, placed emulsion up in rinse bath, and agitated. At intervals of 5 seconds (estimated) remove the remainder of the negatives, one at a time. As they were placed in the solution about 5 seconds apart, each will have had the same development.

(2) With experience, a person can develop twelve 4- by 5-inch films at a time. Probably the best method is to place six in the solution in the same manner as explained in (1) above. After 1 or 2 minutes, start the second six in the same manner, keeping the two sets of six separated throughout development.

(3) Another method is to place the films in the solution in the same manner as given in (1) above, placing them in the solution one at a time and as rapidly as possible. This can be done as the 4- by 5-inch negatives are not so likely to adhere to each other as are the larger sizes. A complete film pack (12 films 4- by 5-inch) can be developed at one time, provided the films are first soaked in water. The same method of developing is then used as when developing regular 4- by 5-inch cut film.

f. Rinsing the negatives.—If the rinse bath used is merely running water, the negatives should be rinsed for about 20 seconds. If a hardener rinse bath is used, they should remain as long as indicated by the directions for using the solution.

g. Fixation.—After rinsing, the negatives should be placed one at a time, emulsion up, in the fixing bath. They should be agitated intermittently about 2 minutes before the white lights are turned on. The negatives should fix for 15 minutes or at least twice as long as it takes the emulsion to clear. The negatives should be agitated several times while fixing.

h. Washing.—The negatives should then be placed emulsion up in the wash water. They should wash for at least 20 minutes and during this time should have their positions in the wash water shifted several times.

i. Swabbing.—When washing is complete, the negative should be swabbed on both sides with a wad of wet cotton, chamois skin, or fine sponge (natural or artificial).

j. Drying.—The negatives should then be dipped in clear water and hung by one corner to dry. When hanging, the negatives should be spaced so that when they curl in drying, they will not touch each other. The emulsions should all face the same direction. After the negatives have been drying for about 5 or 10 minutes they should be inspected on both sides for tear drops. Tear drops are merely large drops of water which form on negatives and will form spots on the emulsion if they are allowed to remain. Any tear drops which have formed should be absorbed by the corner of a blotter or by a piece of dampened cotton or cloth.

246. Developing cut films in tanks.—*a. Advantages.*—The tank system of devlopment, compared with tray development, has the following advantages:

(1) Much faster in quantity work.
(2) More economical in use of chemicals.
(3) More uniform development of different negatives.
(4) Fewer scratches, stains, and spots.
(5) Not necessary to have hands in the solution.
(6) Easier to maintain temperature of developer.
(7) Negatives can be developed at higher temperature.
(8) More thorough rinsing in tanks.
(9) More uniform fixation in tanks.
(10) More efficient washing.

b. Methods.—(1) In the tank system of development it is customary to rinse, fix, and wash, as well as to develop the negatives in tanks. This is accomplished by two methods. The first method, which is employed for developing small roll films and cut films of small sizes, involves the use of only one tank. The film is loaded into a cage, being supported in the cage in proper position by means of its edges which fit into spiral grooves. The cage is adjustable so films of different widths can be accommodated. After the films have been loaded into the cage, they are placed in the tank which is then covered with a lightproof lid. All succeeding operations can be performed in daylight since the lid is so designed that, without its being removed, solutions can be added to or drained from the tank. After the developing solution has been poured into the tank, agitation is secured by gently shaking the tank or by inverting it several times during the period of development. At the completion of development, the tank is emptied after which the negatives are rinsed and fixed. For washing, the lid is removed from the tank. The curved surfaces of the spiraled films impart a swirling motion to the water which assures fast and efficient washing.

(2) The second method of the tank system involves the use of a different tank for each solution, the negatives being transferred in racks from one solution to another as each stage of processing is complete. This method is usually employed for developing large-cut films. This system of development is as follows:

(*a*) *Film hangers.*—When developing films in tanks they are usually supported in bar-type hangers. These hangers consist of a rectangular frame which is made of a type of metal which will withstand the action of photographic chemicals. Around the edges of the frame is a groove into which the film is inserted. The top edge of the frame is hinged to allow insertion of the film. A projecting bar at the top of the hanger allows the hanger to be suspended in the tank during development. This hanger can also be used for developing plates.

(*b*) *Preparation of solutions.*—When the solution used in tank development has not been previously mixed, the fixing bath is mixed first. The rinse bath is placed a few inches to one side of the developing solution, which is mixed last, and placed a few inches to the other side of the rinse bath. Ordinarily the solutions are already mixed and ready for use. When such is the case, they should be inspected for scum. If scum is present, it is extremely important that it be removed from the surface of the solution. This can be accomplished by skimming with a piece of clean cardboard. After the scum has been removed, the solutions should be thoroughly stirred to insure uniform density and temperature throughout. If the developing solution is below the proper level, sufficient replenishing solution must be added to bring the solution to desired level. The developing solution must again be stirred to assure complete mixing. The temperature of both the developer and the fixing bath is taken. If the temperature is not as specified, the solutions must be brought to desired temperature by immersing the tanks in trays of hot or cold water. If possible, arrangements should be made so that the solutions in the tanks remain at the using temperature. This condition will prevail if the temperature of the laboratory can be regulated so that it will be the same as that desired for the solution. The best method to regulate the temperature of the solutions in tanks is to use a water jacket. The temperature of the solutions in the tanks is regulated by the temperature of the water in the surrounding jacket. When a water jacket is not available, the temperature of the solutions can be kept more uniform by placing the tanks in trays of water of the desired temperature. The temperature of the developer should be accurate to at least ½° F.

(c) *Manipulation of film.*

1. After all solutions are ready for use, the timer is set for the desired developing time, the film holders placed in a methodical pile, and the lights extinguished. The films are removed from the holders one at a time and placed in the film hangers. The hangers are then placed in a developing rack which will accommodate about fourteen 8- by 10-inch film hangers.

2. When all of the hangers have been placed in the developing rack, the rack is lowered into a tank of prepared developing solution. The rack is raised and lowered several times to assist in starting the developing action evenly and to eliminate any air bells which might have formed on the surfaces of the separate emulsions. At frequent intervals during the developing time, the rack is raised and lowered to produce agitation of the solution and render even development.

(d) *Rinsing.*—At the completion of development, the rack is lifted from the tank, allowed to drain for a few minutes, and placed in a tank of running water for about 30 to 60 seconds.

(e) *Fixing.*—After rinsing, the rack is again removed from the tank, drained, and placed in a tank containing the fixing bath. The rack is raised and lowered a few times to start fixation and then allowed to stand in the bath until fixation is complete. Fifteen minutes is sufficient time for fixation.

(f) *Washing.*—The rack is removed from the fixing bath after fixation and placed in a tank of running water for at least 20 minutes.

(g) *Swabbing.*—While the negatives can be swabbed and hung to dry in the hangers, it is better practice to remove them from the hangers for swabbing.

(h) *Drying.*—A hook is provided on each hanger for attaching it to a line for drying. If removed from the hanger, a film is supported on the drying line by fastening a clip to one corner.

247. Drying rooms.—*a.* Although negatives are often dried in the laboratories in which they are developed, better results are obtained when a room especially equipped, or a drying cabinet, is used.

b. A room for drying should be free from dust, have a temperature between 75° and 90° F., and be ventilated so as to have a good circulation of air. If the room is not ventilated, its temperature should not be above 80° F. As a rule, ventilation is provided by use of an electric fan. Negatives will dry more rapidly as the circulation of the air is increased. In a room that is ideal for drying negatives, there should be a proper balance of humidity, correct temperature, and rapidity in the circulation of air. If the humidity of the air is insufficient, trays of water should be placed in the room to increase it.

c. Drying cabinets are merely small drying rooms equipped with a fan for circulation and provided with a source of heat. The heat may come either from a gas flame or from an electric heater. Sometimes a large electric bulb is used which, while it may give sufficient heat, is not an economical means of providing heat. Any source of heat used should be placed outside the cabinet in order to eliminate fire hazards. The drying cabinet may be made of metal or wood, but the heating unit should be encased in metal. It is advisable to have the air intake covered with two pieces of cheese cloth to filter foreign particles from the air. Drying cabinets should be so designed that each part of each negative will receive the same amount of air. This is facilitated when the construction of the cabinet is long and narrow. This recommended shape is also less likely to occupy valuable space in the workroom.

d. Ordinarily the temperature of a drying cabinet should not exceed 90° F. in a case in which the negative has been fixed in a potassium alum or a chrome alum fixing bath. If the negative must be dried at a temperature higher than that indicated, it should, before being put to dry, be well soaked for about 5 minutes in a 40 percent solution of formaldehyde. When so treated, however, the temperature of the drying cabinet should not exceed 100° F. if buckling of the film base is to be avoided. A typical form of drying cabinet for negatives is shown in figure 67.

e. The use of a high grade of denatured or pure grain alcohol is sometimes resorted to in order to hasten drying. After thorough fixing and washing and removal of surplus water, the negative is bathed in the alcohol for about 5 minutes and then hung to dry. This method is not recommended for film negatives having a nitrate base since there is danger of the alcohol affecting the base. There is also danger of opalescence appearing when the negative has not been washed sufficiently. This opalescence can be eliminated by returning the negative to the fixing bath.

f. It is not advisable to dry negatives rapidly except in urgent cases. A negative hung in air of moderate humidity having a temperature of about 85° F. will dry in about 30 minutes when the air is well circulated. Using air at higher temperatures and greater humidity will cause an increase in the density and contrast of the

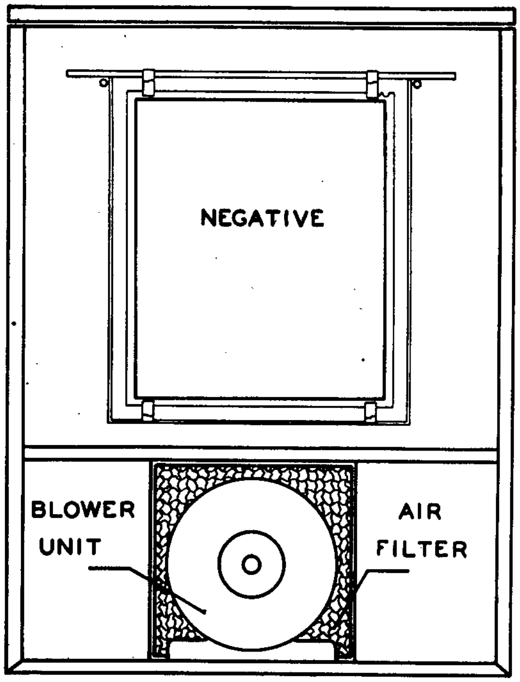


FIGURE 67.—Film drying cabinet.

negative. When a negative is set to dry at high temperature and in a very humid atmosphere with no appreciable circulation of air, it may require a number of hours for it to dry. On the other hand, extremely slow drying may cause an increase in graininess. For this reason, it is necessary to dry miniature film negatives rather rapidly, 30 minutes being sufficiently long.

SECTION V

FINE-GRAIN DEVELOPMENT

248. Factors affecting grain size.—The following factors determine the size of the silver grains in a finished negative:

a. Type of film emulsion.

b. Type of developing solution used.

c. Degree of development.
d. Density.

249. Type of film emulsion.—The size of the silver grains is an inherent quality of the emulsion. As a rule slow emulsions are fine grained and fast emulsions are coarse grained. However, truly fine negative can be obtained only by using a fine-grain emulsion and developing it in a fine-grain developer. Fine grain in a negative is essential when it is necessary that extremely minute detail be registered or when the negative is to be used for making prints of many diameters enlargement. Insofar as the size of grain is concerned, negatives satisfactory for most purposes can be secured by using emulsions which are not especially fine-grained and developing them in normal developers.

250. Developing solutions.—*a.* With the exception of paraphenylenediamene, there is no reducing agent which will develop silver grains to a smaller size than will other agents. While this reducing agent will produce extremely fine grain, it is in disfavor because it causes skin poisoning and will not produce negatives of sufficient density and contrast.

b. It is necessary to use more alkali with some developing agents than with others, but fine-grain developers must include a developing agent which requires little acceleration. Metol is a developing agent of this type and is often used in fine-grain developers.

c. A fine-grain developing solution not only must have a small amount of alakali, but will give better results if a mild alkali such as borax or sodium metaborate is used. When a normal amount of alkali is used in a developing solution, the gelatin is softened to such an extent that the silver grains will shift positions and form into clumps of grains which will appear as, and in effect will be, large-size grains.

d. Sodium sulfite has a slight solvent action on silver halides. In a developer, the sodium sulfite dissolves portions of the silver halide grains. This prevents clumping to some extent and causes the developed grains to be of smaller size. The solvent action increases with the amount of sodium sulfite so that fine-grain developers generally have large amounts of sulfite.

251. Degree of development.—In development, grain size decreases with dilution so that a diluted developer will result in fine grain in comparison with the same developer at full strength. Contrast and speed, however, are also decreased with dilution, so it is necessary to sacrifice some characteristic to better another. As the time of development is prolonged and other factors are constant, grain size increases and therefore is directly proportional to gamma.

252. Density.—The size of the grains varies in the different densities of a negative, being most apparent in large, uniform areas of halftones.

Section VI

NEGATIVE MAKING IN TROPICAL CLIMATES

253. Storage of materials.—The constant high temperature accompanied usually with great humidity of the climate encountered in some localities, particularly the Tropics, requires that special precautions be taken with respect to the storage of some photographic chemicals and especially of all photographic sensitized materials. Directions concerning the storing and shipping of photographic materials and chemicals are covered in Technical Order 24–1–1.

254. Methods.—*a. Courses to follow.*—Either of the two courses may be followed when developing at high temperatures: Bringing the temperature of the water and necessary solutions down to standard temperature by cooling methods; or using a special developer, hardening bath, and fixing bath at the existing temperature.

b. Cooling water and solutions.—When a refrigerator is available, the best method of maintaining a supply of cold water is to lead a section of the water supply pipe through a coil in a refrigerator. If this method is used, the refrigerating apparatus through which the coil is run must necessarily have a capacity commensurate with the amount of cold water required. When only small quantities of cold water are needed, ice or dry ice placed directly in the water is a satisfactory method of cooling. The developer may be mixed with this cold water or ready-mixed developer may be cooled by placing a container of it in a bath of cold water. A solution may also be cooled by placing a container of it in a bath of water and then dissolving hypo in the water. Hypo lowers the temperature of water in which it is being dissolved.

c. Developing.—Plates and films after being exposed should be developed as soon as possible, especially in a tropical climate. Otherwise there may be a loss of density and on developing they may assume a mottled appearance. If the film is new, this is not so likely to occur, but in the case of film which is from 6 to 12 months old, it is not advisable to delay development for more than 1 or 2 days. Before development, all solutions should be brought as nearly as possible to the same temperature. It is most convenient generally, to bring all solutions to the temperature of the wash water. Up to a temperature of 75° F., the regular instructions for development should be followed, modifying the time of development in proportion to its temperature. If an acid fixing bath is employed containing an excessive amount of hardening agents, it is possible to exceed this temperature, although there is danger of pinholes due to the liberation of gas within the film by the action of the acid in the fixing bath on the sulfite and carbonate in the developer absorbed by the film. At temperatures up to 85° F., a strong, rapid developer should be used in conjunction with a chrome alum fixing bath, although the usual kind of acid fixing bath, containing potassium alum, often proves satisfactory. At temperatures up to 95° F., a developer of the kind described should be used in conjunction with a formalin fixing bath. At 95° F., if the negatives are lifted to and from the various solutions by means of the fingers, the emulsion is apt to become separated from the base at the edges; this is called "frilling." When negatives are supported in film hangers during development, fixation, and washing, this trouble will not be encountered. When developing at high temperatures, negatives must be rinsed only for 2 or 3 seconds. Extreme care must be exercised in handling the negatives during the first few minutes of fixation because of the danger of damaging the extremely soft emulsion. All solutions should be at temperatures within approximately 5° F. of one another.

d. High temperature developing solutions.—A developer used for developing negatives at high temperatures is usually concentrated so the negatives will be developed in minimum time. Sometimes it is necessary to use additional potassium bromide because some developing agents will cause chemical fog at high temperatures. Although amidol and paraminophenol hydrochloride are often used as reducing agents in tropical developers, metol and hydrochinon are also often used. Many tropical developers include sodium sulfate to repress swelling of the gelatin.

e. Rinsing.—A negative, after being developed at a high temperature, should be rinsed for 2 or 3 seconds and then placed in a chrome alum hardening bath for a few minutes. The negative must be gently agitated when first placed in the bath. If the emulsion is extremely soft, the rinsing in water may be omitted. Formulas for tropical developers are included in appendix I.

f. Fixing.—When the temperature does not exceed 85° F., a fixing bath containing potassium alum (white) or a chrome alum fixing bath must be employed. At higher temperatures, a bath containing formalin must be used. This type fixing bath can be used as high as 95° F. Negatives should be fixed for 15 minutes. The formulas for these fixing baths are included in appendix I.

g. Washing.—Negatives should be washed 10 or 15 minutes in running water or should be handled in five or six changes of water involving the same time. Radical changes in temperature between the fixing bath and the wash water should be avoided.

h. Drying.—The negatives should be dried in a cool room. Ample circulation of air will prevent reticulation and hasten drying.

SECTION VII

SPEED PROCESSING

255. Purpose.—Quick processing of both ground and aerial negatives is frequently required by the exigencies of military operations. The purpose of speed processing is to produce a usable print in the shortest possible time.

256. Equipment for photography.—Any camera using cut film or film pack may be used. Roll film processing by this method is impractical because of the extremely short development.

257. The developer.—*a.* In this type of work a highly concentrated developer, using a caustic alkali such as sodium hydroxide, is essential. For formula and mixing directions, see appendix I. This developer has good keeping qualities and should be kept in two glass bottles, one being for used solution. After use it may be returned to the container which should be filled each time from the unused solution and tightly corked.

b. While this developer has been used successfully at 95° F., it is recommended that the working temperature be maintained at 80° F. It is not diluted, and the film should not be rinsed in water prior to development. The film is developed at 80° F. for 10 seconds and then transferred to rinse water of the same temperature for 10 seconds.

There are two important reasons for the rinse time equaling the development time:

(1) The action of the strong alkali must be tapered off gradually.

(2) Prevention of dichroic fog which is a characteristic of caustic alkali processing unless remedial measures are taken.

258. Chrome alum hardening bath.—As a caustic alkali developer has an abnormal softening action on the gelatin of the film, a hardening bath should be used, especially in hot weather, after rinsing and just before the negative is placed in the fixing bath. The chrome alum hardening bath deteriorates rapidly, and should, therefore, be freshly mixed every day, or if many films are being processed, two or three times a day. The film should be agitated in this bath for 30 to 40 seconds and allowed to remain in the bath about 2½ minutes.

259. Fixing bath.—While there are formulas for rapid fixing baths, their working life is short and the time saved by their use is so small as to be practically negligible. The regular acid fixing bath is best to use for this type of work. If the temperature of the freshly prepared fixing bath is 80° F., the film will clear in 1 minute, 50 seconds, provided it is kept in agitation during the process. The clearing of the film is all that is necessary to produce a satisfactory print. After the print is made, the negative should be returned to the fixing bath to complete fixation in the regular manner.

260. Preparation for quick processing.—Prepare all working solutions in advance, if possible, so that delays in production of the work may be avoided. The following set-up, a diagram of which is shown in figure 68, may serve as a ready reference:

a. Have the developer ready and checked for temperature.

b. Place rinse bath close to developer and check temperature.

c. Prepare fresh chrome alum hardening bath at same temperature and place it next to rinse water bath.

d. Place freshly prepared acid fixing bath at a convenient distance from the hardening bath.

e. Separated a short distance from the fixing bath is the print developer.

f. Next in line is the print rinse or short stop bath.

g. The print fixing bath is placed at the end of the line. It is advisable to have a separate bath for this purpose at the correct print fixing temperature of 65° F.

h. Lastly, a wash tray for negatives, this may be placed next to the negative fixing bath.

261. Making the print.—As soon as the negative has been cleared of its milky appearance, it is given a brief rinse to remove the surplus hypo. Without draining the water from the negative, place it on the printer glass and lay a sheet of very thin cellophane over it. The sheet of cellophane should be at least three times the area of the negative, free from wrinkles, and should lay flat on the negative. Air is removed by drawing a squeegee with light pressure over the cellophane surface to bring the wet negative into perfect contact with the glass. Care must be taken to see that no water remains on the cellophane to come in contact with the printing paper and cause it to stick. Errors in exposure may be minimized and time saved if three or four prints are made at different exposures. The prints are then developed simultaneously for normal time and the best one selected.

262. Fixing and washing the print.—The print is immersed in a fresh fixing bath at 65° F. for 1 minute. While fixation will not be complete, it will remove enough of the unexposed silver to prevent immediate fading. The print must then be washed for 1 minute in fast running water to remove sufficient hypo to prevent the print from being sticky when finished. A print which has been fixed and washed in this manner will not be permanent. If a permanent print is desired another one, fixed and washed for the correct length of time, should be made.

263. Drying the print.—The alcohol burn-off method is best in this case. Immerse the print in alcohol for about 20 seconds, then pin it to a stick and set it afire. The print must be waved in the air while the alcohol is burning off. It will then be pliable and can be pressed flat. If the print is required to be entirely dry and not pliable, it must be left in the alcohol until the image is visible through the back of the print. Then burn off as before. This method will leave the print with a natural gloss. If a glossy ferrotyped print is required, proceed as follows: Immerse the print in alcohol until the image begins to appear through the back of the print. Then ferrotype print on clean tin in the usual manner. Place tin aside for 3 minutes for print to set. Then apply draft of air from fan. The print should fall from tin in about 2 minutes or total drying time of about 5 minutes.

264. Time required.—A working time of about 8 minutes is required to deliver a quick work print. (See fig. 68.)

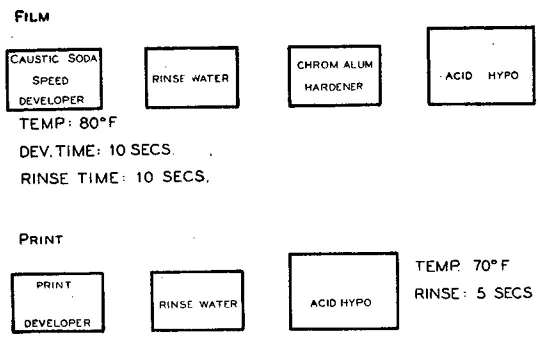


FIGURE 68.—Diagram—speed processing.

SECTION VIII

DUPLICATION OF NEGATIVES

265. Purpose.—Negatives are duplicated for the following reasons:

a. To have a reserve negative in case the original is lost or damaged. This is especially important when it is impossible to make a new negative by rephotographing the subject.

b. To facilitate printing large numbers of prints. When it is necessary to make large numbers of prints from a negative, it is often advisable to make several duplicate negatives which can be printed simultaneously by several printers.

c. To allow distribution of negatives. There are many times when it is desired to distribute negatives for printing in different locations. The desired number of duplicate negatives can be made and distributed where desired. It is often necessary in Air Corps photography to send duplicate negatives to different stations for making prints to be used for instructional or publicity purposes.

d. To improve defective negatives. Many negatives to be duplicated are of incorrect density or contrast. Other negatives are of a type which would require much dodging when prints are made from them. All of these defects can be corrected when making a duplicate negative. Another type of negative that can be improved by duplication is one which must undergo a large amount of etching. Etching is a difficult operation for many photographic technicians. To avoid the necessity of etching, a positive can be made from the negative.

The parts of the positive which correspond to the areas of the negative which need etching can be retouched. This will give the same effect as etching the negatives.

266. Methods.—A positive can be made from a negative or a negaative from a positive by any of the following methods: Using a contact printer, projecting in a projection printer, and photographing the negative or positive while it is being illuminated by transmitted light reflected through it.

a. Contact printing.—When the negative is of the desired size, the easiest method of duplicating is to use the contact printing method. Since film emulsions are much more sensitive than paper emulsions, the printer should be equipped with a rheostat in order that the intensity of the printing light can be reduced. If a rheostat is not available, a blotter can be placed over the ground glass of the printer. The edge of the blotter should be taped to prevent any light which does not pass through the blotter from striking the negative. When it is desired to dodge the negative, any method practiced in contact printing can be used. It is more difficult to obtain contact between a negative and a film than it is between a negative and a piece of sensitized paper. For this reason, when a contact printer is used to make positives from negatives or vice versa it is essential to observe special precautions to effect good contact.

b. Projection printing.—When it is desired to make a duplicate negative of a size different from that of the original, the duplicate negative can be enlarged in a projection printer. Some projection printers can also be used for duplicating negatives smaller in size than the original. When the projection printer is not equipped with a rheostat for regulating light intensity, small lens apertures must be used.

c. Photographing the negative.—This method gives superior results and has an advantage in that the size of the duplicate negative can be regulated easily. A large board with an opening of the desired size is used to support the negative. The negative is placed with the emulsion side facing the lens in this opening. It is held flat by a piece of thin clean glass on each side. Lights are placed so they illuminate a large piece of cardboard or blotter behind the negative. This will reflect an even light over the negative. The exposing of the positive is accomplished in the same manner as exposing a copy negative. A negative can be made of a positive in the same manner.

d. Preserving details of original.—It is essential that the positive used in negative duplication contain as much detail of the original negative as possible. This necessitates that the positive be of low contrast. It should have no trace of chemical fog. Best results are obtained when a nonstaining developer is used.

267. Sensitized material.—*a.* Although all types of emulsions can be used for duplicating negatives, one which is slow and noncolor sensitive is preferable. Using an emulsion of this type will permit longer exposures and will allow the emulsion to be developed under a safelight which will furnish sufficient illumination to develop by inspection.

b. Duplicating film.—(1) There are three distinct types of photographic films which are used for duplicating negatives. The first type is an extremely slow film which has a long scale. When this type film is used, it is necessary to make a positive and to make the duplicated negative from the positive.

(2) The second type duplicating film is used to make duplicate negatives by direct reversal. This means that the film is exposed through a negative and a duplicate negative obtained without making a positive. The process is as follows: The film is exposed through the negative. After it has been developed the metallic image is bleached out. The film is then exposed to the light. When developed the image will then be negative. Positives also can be duplicated by this process.

(3) The use of the third type of duplicating film for making duplicate negatives involves an entirely different principle of photography. This principle is that if a photographic emulsion is sufficiently exposed an image reversed in tones from one obtained by normal exposure will form when the emulsion is developed. This phenomenon is called solarization. The duplicating film is so made that a solarization occurs with comparatively short exposures. When exposed through a negative a negative image can be developed. Duplicate positives can also be made by this direct method.

Section IX

DEFECTS IN NEGATIVES

268. General.—The best photographic practice is always to endeavor to conduct operations so as to avoid errors and defects. The proper selection and storage of materials, care in operation of the camera or apparatus, the correct preparation of solutions, proper condition of trays and containers, and the conscientious following of operation methods that are known to produce satisfactory results, will insure against error to a great extent. However, mistakes are made and if the operator can locate the causes of errors, he can avoid them in the future.

269. Cause and prevention.—The more common defects or errors in negative making are listed in alphabetical order below for easy reference as to cause and remedy or preventive. The procedure followed in finding the cause of a defect in a negative in hand should be systematically conducted. Often several descriptions will apparently fit a certain defect and the correct cause must be determined in order to learn how to correct it and prevent its recurrence. The real cause may be determined by recalling the circumstances surrounding each operation in the production of the negative and reducing by process of elimination the number of possible causes of the defect at each step in production until the true cause is revealed. In studying the defects in negatives, it will be noted that almost none of the remedies given is corrective, but are preventive only, so that the necessity of careful work in the preparation of a negative is essential.

a. Abrasion marks or streaks.—(1) *Appearance.*—Fine, black lines usually resembling pencil scratches and running in the same direction.

(2) *Cause.*—Friction on the emulsion of the film caused by improper handling or storage at some time between its manufacture and development. These streaks may be readily produced by laying two films emulsion to emulsion and sliding one across the other when particles of dust are present between the sensitized surfaces.

(3) *Remedy.*—Great care should be taken in the storage of the film and other sensitized material. The boxes containing such supplies should be stored on end in order that no pressure is exerted on the surface of the emulsion. Care should also be taken not to rub or drag a piece of sensitized material over a rough surface, either before or during development.

b. Air bells.—(1) *Appearance.*—When an air bell occurs during development, it shows as a small transparent spot. Sometimes a minute dark streak leads from the spot. When the negative is rocked in a tray the streak leads from the spot; the streak projects from each side of the transparent spot in the direction the tray is rocked. If the tray is rocked in two directions, the streak will form a cross with the transparent spot in the center. When the air bells occur in tank development, the dark streak usually forms at the lower edge of the transparent spot. When the air bells occur in the fixing bath, they show as small round dark areas.

(2) *Cause.*—The transparent spots which occur in the developer are caused by bubbles of air on the surface of the emulsion which prevent the developer coming into contact with the emulsion. The darkened streaks are the result of the excess oxidation of the developer caused by the air in the bubble. The dark spots which occur in the fixing bath are caused by the pocket of air holding the fixing bath away from the emulsion which allows a slight continuation of development.

(3) *Remedy.*—Immerse film carefully and thoroughly in the developing and fixing solutions; move film during development and fixation in order to break up and prevent air bells. Water always contains some air and when there is a rise in temperature, this air is expelled and gathers in the form of small bubbles on the inside of the tank and also adheres to the surface of the film during the preliminary stages of development. The amount of water needed for development may be allowed to stand for several hours at the temperature required for use before beginning developing operations.

c. Black spots.—See *Spots.*

d. Blisters.—(1) *Appearance.*—Blisters on negatives resemble the familiar ones which arise on the human skin from slight burns.

(2) *Cause.*—Blisters are caused by fluid or gas formed between the emulsion and the film support when the solution has become too warm and has loosened the gelatin from its support. They are also produced by a developer and fixing bath that are both strongly concentrated so that in changing a film from one bath to the other, there is a formation of gas between the emulsion of the film and its support. Blisters are frequently caused by insufficiently rinsing the film after development and placing it directly in a fixing bath having strong acid content. Another common cause of blister is allowing water from the faucet to flow directly on the emulsion side of the negative.

(3) *Remedy.*—The description of the causes of blisters indicates the manner of the avoidance of these defects.

e. Blurred negative.—(1) *Appearance.*—Indistinctness or lack of definition in the negative image.

(2) *Cause.*—The subject was not properly focused on the film, there was movement of the camera or of the subject or through lack of proper adjustment, a portion of the film was not flat in the focal plane of the camera when the exposure was made. A blurred effect is sometimes produced by moisture or haze on the lens or a dirty lens.

(3) *Remedy.*—Care in focusing and in holding the camera; keeping camera in proper adjustment and lens free of moisture or dirt.

f. Brown spots.—(1) *Appearance.*—Brown or sepia-colored spots or small areas on the negative.

(2) *Cause.*—Brown spots are produced by an oxidized developer or by fine particles of chemicals settling on the film prior to development. This defect may also occur during the washing of the negative from rust or other impurities in the wash water.

(3) *Remedy.*—Avoid an exhausted or oxidized developer. Do not use the developing laboratory for the mixing of chemicals. Filter the water used for washing. (See *Spots.*)

g. Crystalline surface.—(1) *Appearance.*—The surface of the emulsion of the negative possesses a crystalline appearance suggesting frost on a window pane.

(2) *Cause.*—Insufficient washing after fixing. Hypo remains in the film and crystalizes.

(3) *Remedy.*—Sufficient final washing.

h. Dark lines.—(1) *Appearance.*—These lines must be divided into two distinct classes; those dark lines which run from dark areas to the more transparent areas of the negative, and those lines which run from the more transparent areas to the darker areas. In both cases the lines are wider, not as clean-cut, and not as nearly parallel as abrasion marks.

(2) *Cause.*—The first class is caused by insufficient agitation of negative in tank development. The cause of the second class is supposed to be of an electrolytic origin.

(3) *Remedy.*—For the first class, more frequent agitation of negative during development. The remedy for this class aggravates the defect in the second class. The only known remedy is to remove all the film hangers from the tank four or five times during the developing period, holding the hangers in a bunch, and allowing the corner of the bunch of hangers to rest on the edge of the developing tank for 10 or 15 seconds.

i. Excessive contrast.—(1) *Appearance.*—The negative record of the high-lights and even of some of the halftones of the subject are in density greatly out of proportion to the record of the shadows, with the result that in a print made from the negative the subject has a strained, hard, and otherwise unnatural appearance.

(2) *Cause.*—Overdevelopment.

(3) *Remedy.*—Obvious.

j. Fading tendency.—(1) *Appearance.*—Sepia or yellow-colored stains or areas in the negative.

(2) *Cause.*—Incomplete fixation, usually the result of insufficient washing. Remnants of the fixing bath left in the emulsion continue their action and in time this defect appears.

(3) *Remedy.*—Always fix and wash the negatives fully and properly. Final washing is as important as any other operation in negative making.

k. Finger marks.—(1) *Appearance.*—Imprint of fingers on the negative.

(2) *Cause.*—Impressing wet or greasy finger tips on the emulsion side of the film before or during development or fixation. If the mark is merely an outline of the finger, it was caused by water or grease on the finger; if dark, by developer; and if transparent or light, by the fixing bath.

(3) *Remedy.*—Keep the hands clean and dry when handling dry film. The natural oils of the body are sometimes present sufficiently on the finger tips to constitute the grease referred to above. Handle film by the edges. When the fingers have become wet with water or solution, wash and dry them before attempting to handle film. Keep the hands out of the fixing bath as much as possible, but whenever it becomes necessary to place them in the solution, always wash them thoroughly before handling the film.

l. Flatness.—(1) *Appearance.*—Insufficient contrast between the highlights, halftones, and shadows in the negative reproduction of the subject.

(2) *Cause.*—Flatness in the negative usually results from underdevelopment, but the subject contrast or lighting may have been flat.

(3) *Remedy.*—Continue development for the proper length of time to reproduce the contrast of the subject.

m. Fog.—Fog is a deposit of silver which does not form part of the image. It may be very dense or only a slight veiling. It may occur on local parts of the negative or it may darken the entire negative. Fog increases the density and decreases the contrast of a negative. Fog may be divided into four types: Aerial, dichroic, light, and chemical.

(1) *Aerial.*—(*a*) *Appearance.*—Slight veiling of the negative or parts of the negative exposed to air during development.

(*b*) *Cause.*—Exposure to air during development, especially when hydrochinon is used as a reducing agent. Most frequently occurs in freshly mixed developers, especially those containing excessive amounts of hydrochinon or alkali. Developers containing formaldehyde or minute traces of copper or tin in the developing solution are also likely to cause aerial fog.

(*c*) *Remedy.*—Use a desensitizer before development. Addition of potassium bromide to developer or addition of used developer to fresh developer.

(2) *Dichroic.*—(*a*) *Appearance.*—Usually a fog of little density consisting of finely divided particles of silver. When viewed by transmitted light, it is pinkish and when viewed by reflected light it is a reddish-green.

(*b*) *Cause.*—Using ammonia as an accelerator. The presence of hypo or an excessive amount of sulfite in developer.

(*c*) *Remedy.*—The fog can easily be removed by treating negative in a weak solution of potassium permanganate. The prevention is obvious from the list of causes. Further prevention is assured by using clean trays for developer and fixing bath.

n. Frilling.—(1) *Appearance.*—Edges of the gelatin become detached from the base. The detached edge of the emulsion may either break off or it may fold over. When the latter happens, it is sometimes possible to smooth out the emulsion when the negative is placed to dry, partially remedying the damage.

(2) *Cause.*—Careless handling; using solutions that are too warm; insufficient hardening of the emulsion from insufficient fixation; a spent fixing bath or one containing an insufficient amount of hardener; excessive washing. Frilling is caused usually by the combination of careless or too frequent handling of the film and any mistake that will render the emulsion of the film soft.

(3) *Remedy.*—Handle film carefully and not too much; have all working solutions sufficiently cold and of proper freshness or strength. Wash film sufficiently, but never excessively.

o. Gas bells.—(1) *Appearance.*—Minute pimples or blisters.

(2) *Cause.*—Transferring a negative from a strongly concentrated developer to a fixing bath strongly acid without thoroughly rinsing the negative after removing it from the developer and before immersing it in the fixing bath. In warm weather, gas bells may appear in developing and fixing solutions of normal strength if the rinsing between development and fixation has been insufficient.

(3) *Remedy.*—Use intermediate hardener rinse bath.

p. Halation.—(1) *Appearance.*—A dark band or area extending from the negative record of intensely bright objects in the subject, suggesting a double image, and appearing in the print as a halo or band of light around the object.

(2) *Cause.*—Photographing an intensely bright object that is surrounded by dark objects. The intense light penetrates the emulsion and is reflected back by the negative support.

(3) *Remedy.*—Use nonhalation film and avoid pointing the camera at bright sources of light.

q. Lack of contrast.—See *Flatness.*

r. Lines suggesting lightning.—(1) *Appearance.*—Fine, opaque, forked, or branched lines resembling lightning.

(2) *Cause.*—Charges of static electricity accumulating on the negative. The static may be discharged while winding the film in the camera, loading or unloading, or at any stage of processing. This defect is most common in roll films but may occur in cut film by rapidly pulling the dark slide from the film holder.

(3) *Remedy.*—Always wind and reel film slowly. Do not touch film with fingers when winding on reels for developing, etc. Avoid dragging film over plush surface. Withdraw and replace dark slides slowly.

s. Negative too dense.—(1) *Appearance.*—Negative image composed of a too heavy silver deposit which diminishes the normal or desired degree of transparency.

(2) *Cause.*—Overexposure, overdevelopment, or a combination of the two. In addition to the heavy image, there may be a veiling of fog produced by overdevelopment. (See *Fog.*)

(3) *Remedy.*—Obvious. The proper degree of transparency for a negative is best found in making a print from the negative rather than by merely looking at the negative as it is held in front of a light.

t. Negative too thin.—(1) *Appearance.*—Insufficient silver deposit forming the negative image which is apparent from the excessive degree of transparency.

(2) *Cause.*—Underexposure, underdevelopment, or a combination of the two.

(3) *Remedy.*—Obvious.

u. Opalescence.—(1) *Appearance.*—A whitish appearance of the emulsion suggesting the color of an opal.

(2) *Cause.*—Use of alcohol to hasten the drying of an insufficiently washed film or lantern slide.

(3) *Remedy.*—Return opalescent film or slide to fixing bath and allow it to remain in that solution until the opalescence has disappeared and then thoroughly wash it.

NOTE.—Use denatured alcohol diluted nine parts alcohol and one part water. This diluted solution will usually not cause opalescence.

v. Opaque spots.—See *Spots.*

w. Pit marks.—(1) *Appearance.*—Fine holes or pits in the emulsion.

(2) *Cause.*—Excessive amount of alum in fixing bath; sulfurous precipitation from the fixing bath when negatives are fixed in a tray; too rapid drying of the negative.

(3) *Remedy.*—Obvious.

x. Purple discoloration.—(1) *Appearance.*—Purple-colored stain.

(2) *Cause.*—High iron content in water with which chemicals were mixed. Frequently occurs when negatives are allowed to stick together in the fixing bath, so that fixation does not take place in the adhered areas of the two emulsions and development continues in them even while the film is in the fixing bath. The spots caused by continuation in development are not a brilliant purple, but black with a purplish cast.

(3) *Remedy.*—If practicable, filter thoroughly all water used for washing. A simple method of doing this is to tie felt or a good straining material over the faucets supplying the running water in which negatives are washed. Avoid impure water in mixing solutions. Negatives must be kept in motion in the fixing bath.

y. Reticulation.—(1) *Appearance.*—Leatherlike graininess or wrinkling of the emulsion.

(2) *Cause.*—Too great a difference in the temperature of the baths or between final wash water and air in which negative is dried. Due to the temperature of a solution or wash water, the gelatin of the emulsion may become badly swollen and upon shrinking will contract irregularly due to the metallic silver incorporated in the emulsion. Also caused by excessive softening of the emulsion followed by a strong hardening bath or a highly alkaline treatment followed by strong acid.

(3) *Remedy.*—Keep all solutions cool and at uniform temperatures. Under tropical conditions, use a concentrated developer and short development. The reticulation effect may sometimes be removed by placing the negative in a 10 percent solution of formaldehyde for a few minutes and drying in front of a fire. Use ample ventilation in drying negatives.

z. Reversal of the image.—(1) *Appearance.*—Positive image when the negative is examined by transmitted light.

(2) *Cause.*—(*a*) Extreme overexposure of negative. This type of reversal is seldom encountered, although quite often certain parts of the subject, such as street lights in exteriors or windows in interiors, will be reversed from overexposure.

(*b*) Reversal of the image is often caused by an unsafe darkroom lamp or by exposing the film to light during development and before fixing. The image which first develops serves as a negative, and on exposure of light, an image is printed on the emulsion below, as in the case of making a print. This develops upon further development, the image produced being a positive.

(3) *Remedy.*—Obvious. Make safelight safe; avoid developing too close to safelight; avoid holding negative too close to safelight for prolonged view during process of development. Also make sure that darkroom is lighttight.

aa. Spots.—(1) *Appearance.*—Spots may be transparent and colored, opaque, or semiopaque, depending upon the cause of each, and may also be sharply defined or the edges may be soft and show a gradual blending to the normal color of the negative.

(2) *Cause.*—(*a*) White or transparent spots, indicating an absence of silver deposit, may be caused by dust on film during exposure or development. The dust prevents the light or the developer from acting on the emulsion lying beneath the particles, and as the dust is washed off either during fixing or washing, the film remains clear. The effect of an air bell is to produce a spot. (See *Air bells.*) Floating chemical dust may settle on a film either before or after development, and the particles of chemicals settling on the film before development may destroy its sensitiveness to light in the portions of the emulsion that they cover. Hypo dust will dissolve away a portion of the emulsion. To produce a white spot after development, the chemical must dissolve the silver. Thus, if particles of potassium ferricyanide adhere to a moist negative during drying, fine white spots having a coatlike tail will result.

(*b*) Opaque, semiopaque, or black spots result from actual particles of grit or foreign matter on the negative or imbedded in the emulsion. Dust or particles of iron rust in the wash water will cling to the film during washing unless carefully wiped off. Particles of hydroquinone, pyro, metol, sodium carbonate, etc., settling on the film before development will cause more development to occur in these spots, while if the chemical dust settles after development, stained spots may be formed. Any undissolved particles left in the developer on mixing or any fine crystals which settle out from the developer when it is cold will settle on the film during development and cause spots. Spots caused by undissolved particles of chemicals in solutions settling on emulsions usually are round or oval with minute "tails" projecting from them, the tails often pointing the direction in which a tray was rocked and usually downward in tank development.

(*c*) Brilliant green, blue, or purple spots on negatives will often result from processing negatives in enamel trays having the enamel chipped away in spots.

(3) *Remedy.*—Keep the camera, magazine, and holder free from dust. Avoid mixing chemicals in the negative making laboratory. See that all ingredients of a developer are dissolved before using the solution. Examine the developer to see that it is free of foreign particles and if not, filter it before using it. Use trays of proper size. (See *Streaks.*)

ab. Streaks—(1) *Appearance.*—Streaks and patches, as in the case of spots, may be dark, white, or transparent. They are considered white if lighter than the surrounding area, and vice versa.

(2) *Cause.*—Dark patches or streaks may be due to uneven development caused by not flowing the developer evenly over the film, by not rocking the tray, or by not moving the film in the developer; a splash of developer on the film before developing; a dirty tray or tank, or using a fixing tray or tank for developing; or light fog. If the edges of the film are clear, the trouble is in the camera, but if fogged, this is due to manipulation in the darkroom. Certain kinds of resinous woods, varnishes, etc., will cause dark fog patches. White or transparent patches may be due to an obstruction in the camera which prevented the light from acting on the plate; a "resist" in the form of oil or grease, which has prevented the action of the developer; a splash of hypo or touching the film with hypo-soaked fingers before development. The hypo dissolves away more or less of the emulsion so that on developing, the portion touched appears lighter than the rest. Drying marks in the form of tear drops or white patches are caused by splashes of water on a dry negative or by leaving spots of water on the film before drying, especially if the film is dried in warm air.

(3) *Remedy.*—The precautions to be taken to avoid streaks suggest themselves when the cause of the streak is traced. In many cases, they can be avoided by care in operations and in the maintenance of apparatus. When placing a negative to dry, always blot off excessive moisture from both sides before leaving it to dry. After negatives have dried for a few minutes, remove tear drops with clean cloth or chamois.

ac. Transparent spots.—See *Spots.*

ad. Uneven development.—(1) *Appearance.*—A streak or area of different density from remainder of the negative.

(2) *Cause.*—Failure to immerse the entire surface of the film simultaneously, or allowing two films to adhere while in the developer, or from not keeping the film in movement by rocking the tray or reversing tank during development.

(3) *Remedy.*—Obvious.

ae. Uneven emulsion.—(1) *Appearance.*—Variations in the thickness of the emulsion.

(2) *Cause.*—Faulty manufacture in that the emulsion was not evenly coated over entire surface of the film.

(3) *Remedy.*—Return sensitized material to manufacturer for replacement, enclosing film in original box, or at least giving the manufacturer's number of the emulsion. This defect is rarely encountered.

af. Uneven fixation.—(1) *Appearance.*—Variation in density of certain areas of the negative.

(2) *Cause.*—Similar to the cause of uneven development except that the defect occurs during fixation instead of during development.

(3) *Remedy.*—Obvious.

ag. White deposit.—(1) *Appearance.*—White granular deposit on surface of negative.

(2) *Cause.*—Exhausted or improperly prepared fixing bath. A sediment of sulfur is deposited over the surface of the negative which whitens when the negative is dried.

(3) *Remedy.*—Replace fixing bath; swab emulsion side of negatives before placing to dry.

ah. White spots.—See *Spots.*

ai. Yellow stains.—(1) *Appearance.*—Areas of the negative colored yellow.

(2) *Cause.*—The commonest yellow stains are oxidization and silver stains which are due to weak or decomposed fixing bath; slightly oxidized or exhausted developer; failure to rinse negative between development and fixation; uncleanliness, dirty trays or impurities carried into developer from the hands; hypo or fixing bath in the developer; insufficient washing; excessive amount of carbonate in developer; leaving negative insufficiently covered in fixing bath, resulting in fixation of area insufficiently covered only as far as first stage, which on exposure to the air will reveal a yellow stain.

(3) *Remedy.*—Obvious.

Section X

HAND WORK ON NEGATIVES

270. Spotting.—The term "spotting" is used to include the most common method employed in improving a negative; that is, the application of color to it for the purpose of hiding a defect. The student soon learns that however much care may be exercised in loading a film or plate holder and in the use of a camera, some particles of dust or foreign matter will find their way to the surface of the film or plate and cause a clear, transparent spot known as a "pinhole." It is particularly important to remove a defect when it appears in a conspicuous part of the picture. Pointed sable hair brushes are used for applying the color in spotting. The smallest sizes must be used for spotting pinholes, while the larger sizes are more efficient for eliminating large defects. Before applying the color to a brush, the brush should be dipped in water. Surplus water is removed from the brush by rotating the tuft of hairs on a blotter. The point of the brush is then dipped into the spotting color. Rotation of the brush will work the color into the hairs without causing spreading of the hairs. Extreme care must be exercised that the hairs are not spread apart or broken by thrusting the brush into the color. With the brush thus charged with color and not too wet, lightly touch the center of the pinhole, holding the brush almost vertical and allowing its point to remain in contact for a brief while. One touch of this kind, skillfully applied, should cover an ordinary pinhole. When the spot is larger, a slight movement of the point may be necessary as well as further applications of color, but each additional application should be made over the previous attempt only after it has been dried. Sometimes negatives are gouged or scratched partially or completely through their emulsion. Spots of this type are difficult to remove and it is often possible to remove them only partially. In many instances, retouching is superior to spotting in removing minute spots on negatives. However, retouching is a slower and more difficult process.

271. Retouching.—Retouching is the application of pencil marks to a negative to build up its density in areas and the reduction of excessively dense portions by the scraping action of an etching knife. Portrait negatives are retouched to remove wrinkles, lines, and skin blemishes, all of which are conspicuous in a photograph. Commercial negatives are retouched to eliminate glaring highlights, to improve modeling, or to remove any undesirable spot or defect. Retouching is somewhat difficult to learn, is tedious work, and requires aptitude. Treatises covering this subject can be obtained in most photographic libraries.

272. Blocking out.—*a.* The term "blocking out a negative" means the application of opaque coloring matter to the negative exactly and neatly around the subject so that in the print it will appear to have been taken against a white background. The materials used in this work are:

(1) Red sable water color brushes as follows: No. 1 for the finest work and Nos. 6 and 18 for other work.

(2) A draftsman's ruling pen.

(3) Mapping pens (or any fine-pointed pen that will allow thick liquid color to run easily).

(4) A straightedge.

(5) A celluloid French (irregular) curve.

(6) A tube or cake of opaque.

(7) A bottle of waterproof India ink.

b. Blocking out is usually done on the back of the negative after the manner of water color painting. The small quantity of water needed to liquefy the opaque is usually carried on a brush. To charge a brush with the color, first wet it with water and then squeeze out the surplus water by pressure of the brush against the side of the water container. Now gently rotate the brush over the color by rolling it between the thumb and fingers. In this way, the brush takes on color on the point and in the proper amount. Always wash and dry a brush at the conclusion of work so that it will be ready and in good condition when again needed.

c. All blocking out should be done with the negative in a retouching desk and with the carrier frame lying back as far as possible and yet permitting the full reflected light to pass through the negative. If the carrier frame is too near the vertical, the color will not run freely from the pen or brush. Turn the negative in any suitable direction in which it is easiest to follow the outline. The image or the different parts of the image to be blocked out should first be outlined with either India ink or liquid opaque. For this purpose a ruling pen is preferable, although a writing pen can sometimes be used to an advantage. After the desired parts have been outlined, opaque should be applied with a small brush to widen the band of color until it is at least one-eighth of an inch wide. A larger brush can then be used to complete the blocking out of the background.

d. If the opaque shows a tendency to dry brittle and crack, which will sometimes happen when used in the cake form, add a few drops of glycerin to it. This gives elasticity to the opaque and will help to make it spread properly without a tendency to dry too quickly or to crack when dry. Always prepare the opaque so that it will spread easily and evenly without streakiness, and if possible, avoid two applications.

e. When outlining the image, it is best to trace around it with the opaque on a ruling pen or on a pen of the kind already mentioned. Work skillfully around the outline of the portions to appear in the print, taking the greatest care possible not to obliterate any of the image. If the opaque gets on the image, correct the mistake at once with the pointed wooden end of the brush wrapped with a piece of soft absorbent cotton, then with the brush slightly moistened with water, removing the extraneous opaque toward the portion to be blocked out. When this is accomplished, do not attempt further work on this part of the negative until the surface is quite dry.

f. In following a straight line, make the fullest use possible of the straightedge. There is a tendency on the part of photographers to try the difficult task of tracing a straight line without the use of a straightedge. Similarly, use the French or irregular curve as much as possible in following curved lines. After the image has been fully outlined by a band of opaque of appreciable thickness, it will be an easy matter to continue the opaque with a brush to the edge of the negative in the manner already explained. This method of blocking out negatives has several disadvantages, among which are:

(1) It involves considerable time and skill.

(2) The opaque will usually scale from negatives filed for any considerable length of time.

(3) Opaque is subject to attack by flies and vermin.

g. Equal results can be obtained by applying a dye to either the emulsion or back of a negative. This is a faster and easier method and the results are permanent. Water solvent aniline dyes in any of the following colors may be used: 1A or 1B red, 1A orange, 1A green, or 1A black. The dye can be applied with a brush or cotton stump. The dye can be applied to small areas with a minute brush or a pen. The best method to employ is to start at the edge of the negative applying the dye until it covers the negative to within about ¼ inch of the image. A smaller brush or the cotton stump can be used to apply the dye along the edges of the image.

SECTION XI

LETTERING OR TITLING

273. General.—Air Corps Circular 95-3 contains explicit directions for titling negatives. This section merely outlines general methods in use.

274. Methods.—*a.* Figures and letters will show sharper on a print when the negative is lettered on the emulsion side, but this necessitates reversing the letters and figures. Therefore, film negatives are usually lettered on the back. An ordinary pen and India ink may be used for lettering the negative, but neater and more legible lettering can be accomplished by using a Wrico set or some other system of mechanical guides. Another method of making titles for negatives is to place a piece of thin celluloid, Kodaloid, or cellophane between two pieces of carbon paper. Then they are placed in a typewriter with a piece of protecting paper over the top carbon. The title can then be typewritten and will be printed on both sides of the celluloid. The celluloid can be attached to either side of the negative with a transparent adhesive.

b. Another method especially suitable for making titles on negatives having dense foregrounds is to cut a section of the desired shape and size from the negative in the place where the title is to be placed. The desired title is printed on paper and copied to exact size to fit the negative using a process film. This copy negative is fitted into the opening which was cut in the original negative. The small negative is held in position by a narrow piece of adhesive tape neatly placed. If this method is not practical, it may be necessary to etch the letters into the foreground.

c. Various types of stamps may also be used for rapidly numbering negatives.

CHAPTER 10

PRINTING

SECTION I

GENERAL

275. Definition.—A print is a positive image on a paper base in which light and dark are correct as viewed in the subject. Prints are generally made by transmitting light through a negative onto a sensitized emulsion on paper. They are classified by the means used in their production such as contact or projection.

276. Importance.—While the necessity for carrying out carefully the lighting, exposing, and processing steps in making the negative cannot be too strongly emphasized, it is nevertheless the finished print which has been the end in view from the beginning of the photographic cycle. If success in printing is to be consistent and not accidental, the photographer must have a working knowledge of the materials and procedures involved and enough skill to obtain in the print a correct monochromatic representation of the tones in the subject.

277. Printing papers.—*a.* Sensitized emulsions used for making photographic prints are listed in three classes:

(1) Bromide.

(2) Chloro-bromide.

(3) Chloride.

b. Bromide and chloro-bromide emulsions are generally used for projection printing, and chloride emulsions which are slower in sensitivity to light are best suited for contact printing.

278. Characteristics of papers.—Printing emulsions are made in many degrees of inherent contrast and speed.

a. The *speed* of the emulsion relates to the sensitivity of the paper to ordinary light and determines the exposure required under a given set of conditions. The speed fits the paper to the printing method or equipment. Papers used for contact printing require less speed than papers used for projection printing because of the differences in the intensity of illumination.

b. The *contrast* of the emulsion fits the paper to the negative. The four most commonly used grades are classified as No. 1 (soft), No. 2 (normal), No. 3 (medium), and No. 4 (hard). The essential difference between contrast grades of the same paper is one of exposure *scale*, a term which relates to the range of light intensities required to produce a print having the full range of useful tones from white to black. This range of light intensities is supplied in printing by the negative, and its contrast becomes the criterion by which the choice of paper is made. The higher the contrast of the paper, the lower is its exposure scale. The purpose of the different grades or contrasts is to offer a selection from which one may choose a paper that will properly render the gradation scale of tones of the negative. For example:

(1) No. 1 is a soft contrast paper and is used to obtain a normal contrast print from a high contrast negative.

(2) No. 2 is a normal contrast paper used in printing from a negative of normal contrast.

(3) No. 3, a medium grade paper, is to be used with negatives that are slightly flat. A negative of this type is out of balance, the density of shadow areas approaching that of highlight areas; that is, the negative is lacking in contrast.

(4) No. 4, a paper of hard contrast, is used when extreme contrast is desirable as in the case of line drawings, and also to print excessively flat negatives in order to assure enough contrast in the print. A negative other than a line drawing negative which requires a paper of this type is generally such that a print containing satisfactory detail and contrast cannot be obtained.

SECTION II

CONTACT PRINTING

279. Precedure.—A contact print is made by exposure of the light-sensitive material when the negative and the printing paper are in direct contact.

280. Operations involved.—The print or photograph is made by placing a piece of light-sensitive paper in contact with a negative, emulsion to emulsion, and exposing the paper to light which passes through the negative to the paper for a sufficient length of time to produce a latent image in the paper emulsion. The latent image is developed into a visible positive image of black metallic silver. The necessary operations are performed in sequence as follows:

a. Place the negative on the glass top of the contact-printing machine, emulsion side away from the glass.

b. Place a sheet of light-sensitive paper in contact with the negative so that the emulsion side of each will be together.

c. Operate the printing machine, thus exposing the paper.

d. Develop, rinse, fix, and wash the print in a manner similar to the same operations performed in negative making.

e. Dry the print.

281. Exposing the paper emulsion.—The glass top of the printing machine must be clean and free from dirt and dust particles. This also applies to the negative. When printing negatives other than aerial, it is the usual practice to mask an 8- by 10-inch negative so that the untrimmed print will have a ½-inch white border. A 4- by 5-inch negative is masked with a ¼-inch border. Lay the masked negative on the printer glass with its emulsion side up. The paper is then placed on the negative, emulsion side down; that is, negative and paper are emulsion to emulsion. The printer top is next lowered sufficiently to force the negative and printing paper into contact and to actuate the electrical switch which turns on the lights. The exposure time should be accurately noted in order that exposure errors, if any, may be corrected. If a timer is not available, seconds must be counted. The operator should become practiced in counting seconds accurately by comparison with a timer or stop watch. The length of exposure depends upon the speed of paper, the color and intensity of printing light, the density of the negative, and the color, if any, of the negative.

282. Dodging.—Sometimes one part of a negative requires more exposure than another part in order to produce the density needed to make the print of uniform tone. The method of locally varying the exposure obtained through a negative is known as "dodging." In practice, dodging is done by using the individual light switches of the printer, turning one or more lights off while leaving others on, for all or part of the total exposure time. If the necessary dodging cannot be accomplished by means of the switches, recourse must be had to the use of tissue paper. This paper is torn into small pieces and placed on the inside diffusing glass of the printer. The resulting action of this method is that the light is controlled in its effect on the sensitized paper directly above the dodging tissue.

283. Safelight.—The recommended safelight for contact printing papers is series 00 which gives bright yellow illumination. The papers are also safe under the safelights used in projection printing with bromide and bromochloride papers but printing quality is more difficult to judge under these lights than with the series 00 which gives more light.

284. Development.—*a.* The tray used in developing contact prints should be slightly larger than the print, and at least half full of working developer solution at the correct temperature. A constant temperature is essential if several prints are to be matched in tone. Prints 8 by 10 inches and smaller dimensions are best immersed in the developer with a sliding movement in such manner that the developer flows over the print rapidly and evenly. The method of immersion of large prints in the developer is described in section III where large prints are usual. The print will remain in the developer for the stipulated time (1 minute, 15 seconds, at 65° F.). The tray should be rocked continually during development, using a change of direction while rocking. The exposure should be such that the print will reach its correct tone in the stipulated time of development. A print is correctly developed when—

(1) Tones that should be black are the best black the paper will yield.

(2) Maximum contrast of the paper has been reached.

(3) Halftones of the print have assumed their proper position in the scale of tones.

b. The factors controlling development are:

(1) Nature, strength, and composition of the developing solution.

(2) Temperature of the developer.

(3) Make of paper.

c. Some precautions to be considered in print development are:

(1) Developers weaken with use and are chemically changed by prolonged exposure to air. Prints should be examined at intervals for any signs of developer exhaustion and fresh developer mixed if necessary.

(2) Prolonged or forced development, or a high developer temperature causes fogging or staining of prints.

(3) A warm developer produces warm tones.

(4) Underdevelopment produces warm tones and low contrast.

d. It is advisable to "ripen" any developer before use. When a large number of prints must be matched in tone, it is essential. The procedure is described in paragraph 288.

e. When prints do not show the desired quality that a printable negative would be expected to give, some error has occurred in the processing. The cause of this error should be correctly determined and precautionary measures taken to prevent its recurrence.

285. Rinsing.—Upon completion of development, the print is quickly transferred to a water rinse for 5 seconds. A secondary rinse in an acid rinse or short stop consisting of 1½ ounces of 28 percent acetic acid in 32 ounces of water is very advisable. This bath, if kept up to strength, will neutralize the alkali developer remaining in the print and relieve the fixing bath of that function, thereby prolonging its working life. If the acid stop bath is used without previously rinsing the print in water, the surplus developer should be drained from the print to prevent the too rapid neutralization of the acid. The print should remain in the short stop bath not less than 5 seconds.

286. Fixation.—*a. Purpose.*—A print is fixed after development for the same reason that a negative is, to dissolve out the silver salt in the emulsion which has not been acted upon by the light and does not form any part of the developed image. The printed image thus becomes permanent.

b. Handling prints in fixing bath.—When the developed print has been thoroughly rinsed, it should be transferred to the fixing bath, and in order that fixation may be even and complete, all prints in this bath should be moved at frequent intervals. Prints should not be allowed to float on the surface or collect in a mass in the fixing bath. It is a good practice to move all the prints in the fixing bath whenever a new print is added to the bath. The hands should be thoroughly rinsed immediately after immersion in the fixing bath and dried before developing operations are continued.

c. Length of fixation.—(1) The question as to how long it takes to fix prints completely is a practical one at this point. In the case of negatives, the unchanged silver salt can be seen to disappear as it passes into solution and by inspection alone it can be judged when fixation is complete. The completion of fixation of paper prints, however, is a very much more difficult matter to judge for the following reasons:

(*a*) The tendency of prints to collect and lie in a mass in the fixing bath.

(*b*) The absence of any visible sign that the unchanged silver salt has been completely dissolved.

(2) The photographer is, therefore, compelled to work by rule. It is imperative that the prints when fixing should be prevented from lying one on top of another. It is almost impossible for fresh hypo to reach the middle of a collection of adhering prints and for silver charged hypo to diffuse out. With a freshly made fixing bath, under normal conditions and with good agitation of prints, fixation is complete in 10 minutes.

287. Washing.—When prints have been sufficiently fixed they should be washed in running water or in several changes of fresh water. The temperature of the water should not be greater than 70° F., nor less than 60° F. for efficient washing. The length of time varies with the time of fixation, the thickness of the paper base, and the temperature of the water, but as an average 30 minutes is the minimum time for efficient washing of single-weight prints and 45 minutes for double-weight.

288. Aerial photographic printing.—*a.* The best print for a mosaic is one that portrays the topographic features of the terrain in both light and dark areas in their correct relation and is of average contrast. In the case of negatives that print flat, it is best to use paper of a grade that will give average contrast in the print. The essential requirement in all aerial photographs for military use is full detail. A further requirement is that the prints composing the mosaic match in tone and color so that the finished product will not have a patchy appearance between prints. This must not be confused with different density of the terrain itself; for example, a patch of wet ground adjacent to a dry or sandy area is a topographical feature and the wet area is naturally darker than the dry area.

b. In order to avoid a patchwork effect in the mosaic and at the same time produce one that will show perfect details in highlights and shadows and will be of such a tone and shade that there will not be a loss of detail when making the photographic copy, it is essential that special methods be employed in printing from mosaic negatives. To meet the requirements of this type of work, the following methods should be adopted:

(1) Obtain sufficient stock solution developer of the same mixing to complete the job.

(2) Obtain sufficient paper of the same emulsion number, contrast, and expiration date.

(3) Maintain the working developer at the prescribed temperature.

(4) Ripen the first batch of working developer just before use by developing for 5 minutes four sheets of paper that have been exposed to white light. When mixing the second and subsequent batches of working developer, retain as a ripener one-fourth of the used developer and add it to the fresh working solution. Ripening is sometimes referred to as silver loading. This chemical action has a definite relation to the working properties of a developer.

(5) Select a negative containing as many features of the terrain as possible.

(6) From this negative make a master print, keeping in mind the requirements. The printing light should be so regulated that the exposure will be not less than 10 seconds. Development time will be not less than 1 minute, 30 seconds. It is good practice to try two or more grades of paper to find which contrast is best suited to the negative to obtain the desired result. Several prints should be made from the negative. These prints are examined in daylight or equivalent and the best one selected as the master print. The selected master print is immediately duplicated by making three more prints to match exactly in case of damage to the original.

(7) Keep one master print wet and conveniently located to the developer so that subsequent prints can be matched in processing.

(8) Prints from other negatives of the job will now be secured whose detail will match corresponding detail in the master print.

(9) When dodging is necessary to obtain even prints, use the individual light switches of the printer.

(10) Develop not more than 15 prints in 48 ounces of working solution and do not use the developer more than 1 hour.

(11) After final washing of prints, immerse them in a softening bath for 5 minutes.

(12) Remove excess water by placing prints on an inclined surface to drain. Then blot with gentle pressure and without use of print roller.

(13) Place prints, emulsion side down, on drying rack.

(14) All laboratory procedures not specifically mentioned follow the regular practices.

289. Precautions and directions.—*a.* Do not leave trays scattered around. Working systematically not only saves time but avoids mistakes. The trays should always be arranged in the following order from left to right: developer, rinse water, and fixing bath.

b. After a print has been immersed in the fixing bath, thoroughly rinse the hands in clean water and dry them before proceeding with developing operations, otherwise the fixing bath will be carried on the hands into the developer and render the latter unfit for photographic use.

c. Do not leave the paper box open or have unexposed sheets of paper out of the box. Photographic-sensitized materials are expensive, and therefore should be handled carefully to avoid waste.

d. Always keep chemicals fresh and pure and in clean containers. Rinse chemical solutions from outside of containers.

e. Do not carelessly throw spoiled paper around the darkroom. Keep all working material in its proper place at all times. Spoiled or discarded prints must be torn sufficiently to render them useless.

f. In general, always be orderly, cleanly, and systematic in darkroom work. Good contact printing requires it.

290. Softening contrasty prints.—It sometimes happens that No. 1 paper will not be within the range of a negative that is very contrasty so as to give the desired detail in the print. If the paper is given a slightly increased exposure and then soaked in clean water for a few minutes before development, an appreciable softening of the contrast will result. It is desirable when soaking the print to place it emulsion side down in the water as a protection from the safelight.

291. Use of potassium bromide.—*a.* The successful printer must thoroughly understand the use of potassium bromide in the developer. All developers for paper require a certain amount of potassium bromide to keep the whites of the print clear. For convenience, therefore, saturated solutions of potassium bromide are kept in the printing laboratory. When printing from negatives that require a soft grade of paper, bromide must be added to the developer if the whites do not appear clear or if the prints show any indication of fog on the masked border. Even if fogging of the print does not result, bromide should be added to the developer for soft papers if the same color of print is desired from soft papers as from the hard. Bromide papers almost without exception require at least one-third more potassium bromide than chloride papers.

If the additional bromide is not used with these papers, development cannot be prolonged sufficiently to secure the rich, deep printing tone that is necessary for good bromide prints. The greenish tinge in prints that is usually laid to the excessive use of potassium bromide is many times really caused by underdevelopment. The greater the amount of bromide in the developer the longer should be the time of development. Whenever greenish or brownish tones are encountered in printing, recalculate the developing formula to see whether the amount of potassium bromide is in excess of that required. If found that it is not, development should be continued for a longer time and the difficulty will usually disappear.

b. The saturated solution of potassium bromide is added in drops to the working solution of the developer, use being made of the ordinary type of druggist's eye dropper for this purpose. One drop of saturated potassium bromide solution should be added to each 4 ounces of working developing solution. If this should prove insufficient, add one or two drops more, test by the development of a print, and if additional bromide is still desired, add this quantity, followed in each instance by a test until the desired result is obtained. A saturated solution of potassium bromide is strong and a very small quantity will affect the developer, therefore great care must be used in accurately measuring the bromide in drops when adding it to the working solution of the developer.

c. Occasionally when stale paper is used, the addition of potassium bromide to the developer may not prove as efficacious as the use of potassium iodide. The proportion of the latter salt ordinarily added to a normal paper developer is not more than one-eighth of a grain to each ounce of the working solution.

292. Uniform tones.—Photographic papers have varying degrees of color or warmth of tone built into them in process of manufacture. It is sometimes desired that the tone of the prints be pure black with all trace of color eliminated. This can be done by the use of potassium sulfocyanate (commonly known as K. O. drops) added to the developer in drops until the desired tone is obtained. While this chemical tends to add slightly to contrast and shorten the life of the developer, it is very useful in obtaining uniform tone when matching prints. A range of tone from pure black to almost purple is possible according to the quantity used in the working developer. From a stock solution of 25 grains to 1 ounce of water, the amount required is added to the working developer. Usually from 5 to 15 drops in an 8- by 10-inch developing tray will have the desired effect.

Section III

PROJECTION PRINTING

293. General.—In projection printing a lens is used to project the negative image on a sheet of sensitized paper. The size of the projected image is dependent upon the distance from the lens to the sensitized paper, the size of the negative, and the focal length of the lens, and such image may be larger, smaller, or of the same size as that of the negative.

294. Projection printers.—A projection printer must include a means of evenly illuminating a negative, a negative holder, a lens, bellows, and an easel or paper holder. (See fig. 69.) A study of figure 69 will show that by means of a reflector and condensing lenses or diffusing medium, the light from an incandescent bulb is dis-

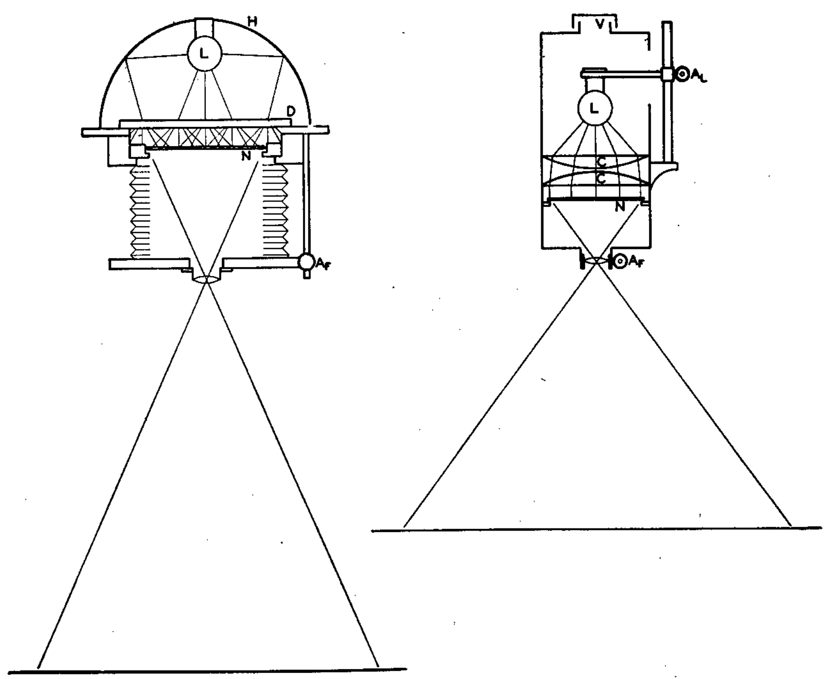


Figure 69.—Projection printers.

tributed evenly over the negative and the enlarged image is projected on the easel. In a vertical type printer, the negative is placed above the paper both of which are in a horizontal position. Some projection printers are so designed that they can be used vertically or tilted and used as horizontal printers.

295. Types of paper used.—*a. General.*—Although it is possible to make projection prints on chloride paper, provided a light of sufficient intensity is used, most projection prints are made either on bromide or bromo-chloride emulsions. Since these two types of papers are more expensive than chloride paper and the sizes of the sheets are usually larger than those used in contact printing, it is essential to use test strips for trial exposures and to use all other possible precautions to hold the amount of paper consumed to a minimum.

b. Bromide.—Bromide paper is available in single and double weights, white, buff, and cream-colored stocks, and in a variety of surface textures. Different brands of bromide paper vary in speed as do the brands of chloride paper. This makes it impossible to make an accurate comparison of speed between the two types of papers but bromide paper is about 40 to 50 times faster than chloride paper.

c. Bromo-chloride.—Many technicians prefer bromo-chloride paper to bromide papers claiming the bromo-chloride papers have the desirable characteristics of both bromide and chloride emulsions. Another advantage of bromo-chloride paper is that it has a speed fast enough for projection printing but not so fast as to prevent its use in contact printing. This is an advantage when it is desired to make contact prints and projection prints from the same negative and have the same color of stock, tone, and surface in both the contact and the projection prints. Ordinarily, bromo-chloride papers are about 5 to 20 times faster than chloride papers and from 5 to 10 times slower than bromide papers. Bromo-chloride papers are usually manufactured only in a normal grade of contrast, but are sometimes made in normal and medium contrast. There are no bromo-chloride papers manufactured in more than two contrasts. Two reasons why it is not important to have the variety of contrasts in the papers used in projection printing as it is in those used in contact printing are as follows: as a rule, projection prints are made only from negatives of good quality; the contrast of prints made on bromide or bromo-chloride paper can be altered by varying the exposure, the developing time, and the strength of the developer.

d. Safelights.—Both bromide and bromo-chloride papers can be handled safely with a No. O (orange) or No. OA (light green) safelight. Prints can be judged more accurately when the No. OA safelight is used.

296. Characteristics of projection printers.—*a. Illumination.*—Either incandescent bulbs or fluorescent tubes which are contained within the apparatus are used. The illuminant, in most cases, is an incandescent lamp inclosed in a lamp house which is part of the printer and is of the correct intensity for bromide or bromo-chloride emulsions.

b. Focusing.—(1) The size of the projected image is determined by the distance from the lens to the easel. In order to have a sharp image on the easel each time the distance from the lens to the easel is increased or decreased, the bellows extension must be respectively decreased or increased. When an exceptionally dense negative is being projected, the illumination may be so weak that there is difficulty in determining when the image is sharp. This difficulty can be overcome by substituting a negative of less density for determining the focus. This substituted negative should be one that is critically sharp. A negative of a line drawing or a transparent focusing chart is ideal for this purpose.

(2) Some projection printers focus automatically, a system of levers bringing the image into focus when the distance from the lens to the easel is altered.

c. Reducing attachments.—In order to make a projection print at a scale of 1 to 1, the bellows of the printer must be extended two focal lengths. The bellows extension must be still greater when making a print smaller than the negative. Reductions can be made in any projection printer provided the bellows can be sufficiently extended. When the bellows extension is not sufficient, a reducing attachment can be used. A reducing attachment is merely an extra section of bellows, one end of which can be attached to the main bellows and which has facilities for supporting a lens in the opposite end. The lens which has been removed from the printer may be used or the attachment may include a special lens. This special lens can be of shorter focal length and slower speed than the regular lens. Some reducing attachments are provided with a graduated scale by which the size and focus of the image is secured mechanically.

297. Making a projection print.—*a. Operations required.*—The following operations must be followed in making a projection print:

(1) Preparation of the negative.

(2) Inspection of the printer.

(3) Insertion of the negative in carrier.
(4) Masking the negative.
(5) Composing the print.
(6) Preparation of solutions.
(7) Making and processing a test exposure.
(8) Exposing the print.
(9) Inspecting the print.
(10) Dodging.
(11) Diffusing prints.
(12) Developing.
(13) Fixing, washing, and drying.

b. Preparation of negative.—Before starting to make a print, the negative should be examined for pinholes, scratches, finger marks, and dust. Pinholes and scratches should be removed by spotting or retouching. Dust can be removed by brushing lightly with a soft cloth or camel's-hair brush. Finger marks can be removed by swabbing with a soft cloth dipped in carbon tetrachloride which is also an excellent method for removing dust.

c. Inspection of printer.—The inspection of the printer should include the following:

(1) Checking the lens for cleanliness and determining if diaphragm is working properly.

(2) Checking lights, switches, and movable parts of printer.

(3) If the printer has automatic focus, the accuracy of the focus should be checked, preferably by using a focusing chart.

(4) With negative removed from carrier, the evenness of illumination should be tested and if found to be irregular, corrected by proper adjustment of lamp.

d. Insertion of negative in carrier.—The glasses of the negative carrier should be thoroughly cleaned. The negative must be placed in the carrier, emulsion toward lens. Sometimes it is better to anticipate the areas of the image which will need the most dodging and place the negative in the carrier in such a position that these areas of the image will be closest to the operator. The negative should be centered in the carrier.

e. Masking the negative.—Located near the negative on most projection printers are four masking slides. These are for the purpose of cutting off all light which does not pass through the negative. Surplus light, if not eliminated, may fog the printing paper. When a printer does not contain masking slides, negatives should be masked in the negative carrier. While either of these masking devices can also be used to make white borders on prints, it is much better practice to border prints by means of masks in contact with the print.

f. Composing the print.—When a print is to include the entire area of a negative, the composing of the print is a matter of correct spacing of the image on the easel. Frequently it is not necessary to include the entire image of the negative in the print. In such cases, it is often possible to improve the composition of the negative by local masking and to eliminate some undesirable features of the negative. The ability to alter the composition of the negative in making the print is one of the advantages of projection printing.

g. Preparation of solutions.—The trays for the developer and rinse bath should be slightly larger than the largest print to be made. The tray for the fixing bath should, when possible, be at least twice as large as the other trays. The trays should be spaced apart at distances which will not allow one solution to be splashed into another. Since prints of large size are difficult to keep separated in the solutions, liberal quantities of solutions should be placed in the trays.

h. Making a test exposure.—After the above preparations have been completed, the next step is to make a test exposure as follows:

(1) With the lens wide open, study the projected image for contrast. The degree of contrast will determine the contrast of the paper which should be used.

(2) With the light on, close the diaphragm until the image on the easel appears to have a brightness that will necessitate at least 10-seconds exposure. The ability to judge the brightness of an image which will print in this time requires practice but is an excellent way to judge exposures.

(3) Place a strip of the paper to be used on the easel in such a manner that it covers an area of fairly uniform and average density. Make four exposures of 4 seconds, each covering up sections of the paper in such a manner that the sections receive consecutively 4-, 8-, 12-, and 16-seconds exposure. When the test has been developed, the correct exposure for the print can be accurately determined. A second method of testing is to place the test strip on the easel in a position which will include a highlight, halftone, and a shadow of the image. Expose for 10 seconds, and from the developed test determine the correct exposure for the print.

i. Exposing the print.—Place a whole sheet of paper on the easel. Expose for the time which was estimated from the test to be proper. Develop for the normal time, rinse thoroughly and fix for 1 minute. Rinse and carry in a tray to daylight or white artificial light for inspection.

j. Inspection of print.—The print should be inspected for over-all density. If too light or too dark, the exposure must be respectively increased or decreased. If the print is decidedly too contrasty, a softer grade of paper must be used. If decidedly flat, use a grade of paper that will give more contrast. If the contrast is only slightly incorrect, the proper contrast can be secured by varying the exposure and developing time. The contrast of prints can also be slightly varied by changing the intensity of the light. This can best be accomplished by means of a rheostat if the printer is so equipped, or by regulating the size of the diaphragm opening. Long exposures by weak light give greater contrast than short exposures with a more intense light. If the print as a whole is correct but there are areas which may need more or less exposure, the amount of dodging which will print these areas to the desired densities must be estimated. The print should also be inspected for spots which might be caused by dust on the negative or by fog and stain. If any of these defects are discovered, proper measures must be taken to prevent their appearance in the next print.

k. Dodging.—(1) If large numbers of projection prints are to be made from a negative, the best method to use for dodging is to dye the negative locally. However, a negative properly dodged by the application of dye for contact printing might be overdodged or underdodged for projection printing because the emulsions of the papers used for projection printing are not proportionately sensitive to the colored light transmitted through the dyes.

(2) When the negative is not dyed, dodging is accomplished by holding back light from certain areas of the image during part of the exposure. This is accomplished by holding the hands or a piece of cardboard between the lens and the easel. Small areas, especially those near the center of the print can be held back by interposing small pieces of blotter or cardboard of the proper size and shape between the lens and the paper. By this method, the central areas of the print can be held back without affecting areas along the edges of the print which are of proper density.

(3) Areas of the print which are too light can be printed in by means of a cardboard shield containing a hole. By holding the shield a few inches above the print, additional exposure can be given to the desired areas by allowing the light passing through the hole to fall on these areas. A device for printing in areas of prints is shown in figure 70. This device consists of a piece of cardboard in which is cut a rather large opening. A circular piece of cardboard containing a variety of sizes and shapes of small openings is centered on the cardboard in such a manner that the desired opening can be turned to the

opening in the base. The size of the cardboard and openings are somewhat dependent on the size of the prints to be made. In fact, two sizes should be available in the laboratory; a small size for dodging prints, not larger than 11 by 14 inches, and a larger size to be used with large prints.

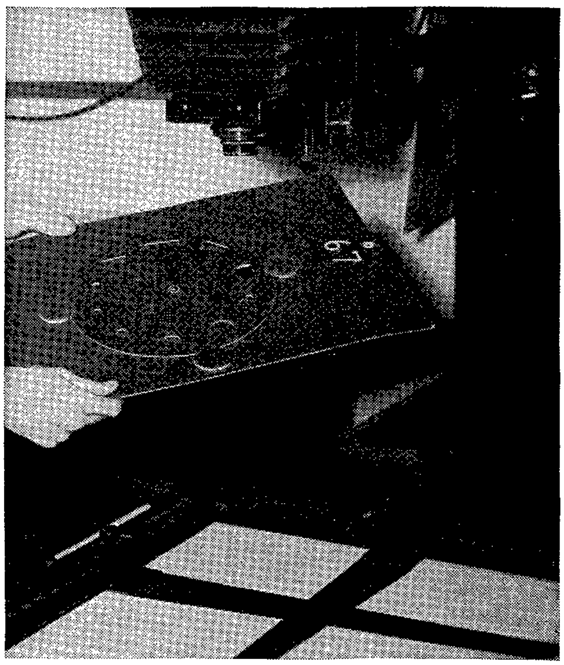


FIGURE 70.—Dodging device.

(4) In dodging, both when holding back and when printing in areas care must be used not to overdo the lightening or darkening of the areas and to blend the dodged area into the rest of the print. Blocking can be secured by continuous movement of the dodger, not only laterally, but also vertically. Whatever method of dodging is employed, there is one rule which must be followed: *Always underdodge* when an area is lightened or darkened to the exact shade it apparently should be. This area of the print will have an unnatural and faked appearance. Therefore, it is better to allow the area to remain a trifle darker or lighter than it should be printed if dodging were necessary.

l. Diffusing prints.—(1) Prints are diffused in projection printing for the following purposes:

(*a*) To give pictorial effects.

(*b*) To reduce the prominence of defects or unretouched portrait negatives or to make rough retouching less prominent.

(*c*) To decrease the graininess or other defects of copy negatives.

(2) The following devices are used for diffusing:

(*a*) Optical diffusing disks can be used by attaching to the lens or holding near the lens during part or all of the exposure. They diffuse by slightly distorting the light rays. Optical disks usually are in sets, each disk giving a different degree of diffusion.

(*b*) A more satisfactory device for diffusing is a piece of crumpled cellophane. This can be held a few inches from the lens during all or part of the exposure, depending upon how much diffusion is desired. The sheet of cellophane can be held still or it may be moved during exposure.

(*c*) A third method is to stretch a piece of chiffon or bolting cloth over a wire ring. This can be used in the same manner as the crumpled cellophane.

m. Developing the print.—(1) The average developing time for bromo-chloride paper is 1½ minutes while that for bromide paper is 2 minutes. These developing times are longer than that used for chloride paper, and stains on prints may appear unless care is taken to see that the developer is not exhausted.

(2) Prints should be placed, emulsion up, in the solution with a sliding motion. It may be found necessary to roll large prints, especially those on single-weight paper. With the roll held in the left hand, the print is placed in the developer by pulling the outer edge of the roll underneath the developer, allowing the print to unroll at the same time.

(3) The contrast of both bromo-chloride and bromide emulsions, but especially that of the latter, is very susceptible to variation of exposure and development. Short exposure and prolonged development tend to produce the maximum contrast in the prints. However, development beyond maximum contrast tends to produce fog. The range of developing time used for bromo-chloride paper is from 1 minute, 15 seconds to 2 minutes, 30 seconds. The range for bromide paper is from 1½ to 3 minutes. This variation of developing time of projection prints is not only permissible but must be practiced to secure the finer degrees of contrasts which are often necessary for good prints.

n. Fixing and washing.—(1) Prints should be fixed emulsion up. If the prints are of large size, double fixing baths should be used. In the fixing of large projection prints, especially those having wide borders, there is an inclination to overwork fixing baths. This must be avoided as silver bromide emulsions (especially when the emulsion contains some silver iodide, which it usually does) are considerably more difficult to dissolve than the silver chloride used in contact printing papers. Large prints will pack together in fixing baths. For this reason, considerable attention should be given to the separating of prints while they are fixing. With proper attention the prints will fix in 15 minutes.

(2) When the projection prints are small, they may be washed in the same manner as contact prints. Unless extremely large washers are used, large prints must be washed in trays since prints of the larger sizes are often damaged in mechanical washers and will not be washed efficiently because they tend to cling together. When washed singly, at least six changes of water are needed and each change should take about 5 minutes.

Section IV

FINISHING PRINTS

298. General.—The finishing of prints includes all treatments given to prints from the time they are removed from the fixing bath to their final delivery. Therefore, washing, softening, drying, trimming, mounting, and spotting of prints will be explained.

299. Washing.—*a. General.*—Although, during washing, chemicals diffuse from the base of a print as well as from the emulsion, it is more difficult to wash prints than negatives on film because the hypo is held so tenaciously within the fibers of the paper. For efficient washing of prints the stream of water should be sufficient to produce a complete change of water within the washer every few minutes. The prints should be kept moving and well distributed.

b. Temperature of the wash water.—(1) The temperature of the wash water has a definite bearing on the rate at which the chemicals diffuse from prints. The ideal temperature range for wash water is from 60° to 70° F. At temperatures below 60° F. the time must be increased considerably and if the temperature exceeds 70° F. it may be necessary to use an auxiliary hardening bath before washing to prevent undue softening of the emulsion.

(2) When prints are removed from a fixing bath and it is necessary to wash them in water of a decidedly different temperature, unequal expansion or contraction between the base and the emulsion will cause blisters or frills. Under these conditions it is advisable to place the prints for a few minutes in a tray of water having a temperature midway between that of the fixing bath and the wash water.

c. Washing in trays.—(1) Although the major portion of prints made are washed in mechanical washers, it is often necessary to wash them in trays. Two trays having deep sides should be used. The size of the trays is determined by the size and number of prints to be washed. Both trays should be filled almost completely with water and the prints placed emulsion up in the first tray after the fixing solution is drained from them. After the prints have been separated one at a time, the water should be drained from the tray and the tray again filled with water. The prints should then be transferred one at a time to the second tray. Here the treatment given in the first tray is repeated when the prints are again transferred to the first tray. Six complete changes from one tray to another, allowing 5 minutes between changes, is sufficient for single-weight prints. Double-weight prints should be given 8 to 10 changes.

(2) A second method of washing prints in trays involves the use of a siphon. The siphon is fastened to the edge of a large deep tray. A hose connects the siphon with a faucet. Water from the hose passes through an outlet into the upper surfaces of the water with sufficient force to agitate the prints well. At the same time, the heavier chemically contaminated water is siphoned from the bottom of the tray. This method of washing is quite efficient provided the prints are rinsed thoroughly in two or three changes of water before being placed in the large tray to which the siphon is attached.

d. Mechanical washers.—Although there are many different designs of mechanical washers, they may be divided into three types; open cage washers, closed cage washers, and rocker washers.

(1) The open cage washer consists of a round tray in which a metal cage containing the prints revolves in a horizontal direction on a vertical axis. The cage is open at the top and so balanced that water spraying into it from the top causes it to revolve. Prints are kept separated by means of flexible aprons. These aprons are fas-

tened to the top of the washer and the lower edges extend slightly below the surface of water. As the cage revolves, the prints strike these edges and change position in the water. Although the tray or tank of water is shallow, it is made so that the water drains from the bottom. In some models, the water is completely drained at intervals by means of a siphoning device. This open cage type of washer is very satisfactory for washing prints. It is efficient in its action, seldom damages prints, and it is easy to place prints in it or remove them. Large prints can be successfully washed provided too many are not undertaken at the same time.

(2) Another type of washer consists of a tank in which a cage containing the prints revolves on a horizontal axis. The cage may be driven by a water wheel attached to it or by an electric motor. Water enters the washer from the top and is siphoned from the tank at the bottom. This type washer is quite efficient for small prints, but prints as large as 8 by 10 inches are inclined to form rolls which not only prevent efficient washing but are often responsible for tears and other damages to the prints.

(3) The rocker type washer is really equivalent to two trays fastened together with a high separator between. The connected trays are balanced on a pivot in such a manner that water flows along one side of the separator into one tray until it is full. The weight of the water causes this tray to move downward which allows all the water it contains to escape through holes in the end of the tray. At the same time, the separator is moved into a position which will allow the opposite tray to fill and cause the second tray to empty while the water again starts running into the first tray. The water draining completely from the trays and the complete shifting of the position of the prints each time the trays are tipped results in very complete washing of prints. This type washer is also economical in the use of water. Its rocking action is gentle and prints washed are seldom damaged.

e. Testing prints for hypo.—While it is not necessary to test each batch of prints washed for the presence of hypo, it is good practice to make a test once in a while to prove or disprove the efficiency of the washing methods and time of washing being used. In chapter 3, two methods of testing prints for the presence of hypo are explained. The formula to be used in performing the test is included in appendix I.

f. Washing time.—(1) When additional prints are added to a batch of prints which are partially washed, the hypo from the added prints will immediately diffuse into those which have been washing.

This makes it necessary that the timing of the washing be started when the last prints were added.

(2) The tanks of mechanical washers have a large capacity. When a batch of prints is removed from the fixing bath and placed directly in the washer, a considerable quantity of the fixing solution is carried into the washer. This quantity will be halved if the prints are given one complete change of water before being placed in the washer. This quantity will be further reduced by a second and third change of water. For this reason, it is much better practice to wash prints with two or three changes of water before placing them in the washers.

(3) The time necessary to wash prints is dependent upon the completeness of fixation, the amount of agitation they receive while being washed, the completeness and rapidity with which the water is changed, and whether the prints are on single- or double-weight paper. The time is also slightly dependent upon the temperature of the wash water. While it is most necessary that prints be completely washed, it is poor practice to wash them for a needlessly long time. Prolonged washing may cause any of the following:

(*a*) Excessive softening of the emulsion.

(*b*) Blisters and frills.

(*c*) Stretching of prints.

(*d*) Accumulation of slime on the print from impurities in the water.

(4) The correct time of washing must be established by tests which will prove the efficiency of the methods used. However, under favorable conditions, 30 minutes is the minimum washing time for single-weight prints and 45 minutes for double-weight prints. If absolute permanency is essential, a satisfactory hypo elimination test should be employed. The formula for the eliminator recommended will be found in appendix I.

300. Use of softening baths.—*a. Purpose.*—The emulsion of prints is frequently hardened to an extent that if the prints are dried without having received some special treatment, certain difficulties as follows will be encountered:

(1) An inferior gloss will result if the prints are ferrotyped.

(2) The prints will curl excessively.

(3) The emulsion will often crack when an attempt is made to straighten the prints.

b. Treating prints in glycerin baths.—The difficulties caused by the gelatin of prints being too hard can be prevented by placing the prints immediately after they have been washed in a solution of glycerin. The solution is made by adding one part glycerin to 10 parts water. The prints should be left in the bath for at least 5 minutes. If the softening action is not sufficient, the amount of glycerin can be increased or the solution can be heated to about 80° or 90° F. The prints are not rinsed after being treated, but are placed immediately on blotters, drying stretchers, or ferrotype plates.

c. Use of carbitol acetate.—Carbitol acetate (diethylene) may be used as a substitute for glycerin for softening prints. The proportion used is the same as for glycerin and the solution is used in exactly the same manner.

d. Precautions in softening prints.—(1) Prints which are to be dried in belt driers should not be treated in glycerin baths. In fact it is often necessary to run prints which are to be so dried through a supplementary hardener to prevent apron marks. Extreme care must be used that no prints which have not been completely washed are treated in the softening bath. When this is done, hypo from the prints will pollute the bath and ensuing batches of prints will be contaminated. To avoid this danger, it is good practice to mix the bath in small quantities which can be frequently discarded.

(2) Besides softening the gelatin of emulsions, softening baths will make the paper base of prints more flexible. Prints so treated are less inclined to curl and are more easily flattened because of the increased pliability.

301. Drying.—Prints are dried by the following methods: Placing on drying racks, running through belt dryers, and ferrotyping.

a. Drying on racks.—(1) A drying rack consists of a stand with grooves for holding a number of stretchers. These stretchers or leaves are wooden or metal frames across which is stretched cheesecloth, marquisette, or bobbinette. The frames are supported in the drying rack in a horizontal position, one above the other, and can be partially withdrawn for convenience in loading the rack.

(2) Drying prints on these stretchers is a superior method since it will not change the tones or cause distortion. For these reasons, it is employed for drying mosaic prints. The prints being placed on the stretchers should have the surplus water removed, either by blotting or by placing in piles a few prints deep on an inclined flat surface, and lightly squeegeeing. The prints are placed on the stretchers emulsion side down. It is better to place them with the emulsion side up for a few minutes, then turn them so the *emulsion side is down until drying is completed.*

b. Belt dryers.—(1) A belt dryer consists of a drum over which travels a wide cloth belt or apron. The drum is motor-driven and heated by gas or electricity. The rate at which the prints dry is regulated by the degree of heat of the drum and the speed at which the apron travels around the drum.

(2) The surplus water should be removed from prints by blotting or squeegeeing before they are placed on the apron for drying. The prints are placed on the apron emulsion down and should dry properly by being passed once through the dryer. This can be achieved by regulating the amount of surplus water removed from the prints before drying and by regulating the speed of the apron and the heat of the drum. In drying large light-weight prints, it is usually better to drain them only slightly before placing on the apron.

(3) When using the belt type of dryer, the following precautions must be taken: the heat must not be excessive, otherwise the tones of the prints may be changed. Excessive heat may also make the prints too brittle. The emulsion of the prints must be sufficiently hardened in a fresh fixing bath containing a hardener, otherwise apron marks (indentations of the weave of the cloth apron) may be impressed on the surface of the prints. Great care must also be taken to see that the prints have been well washed, otherwise those still impregnated with the fixing bath may transfer it to the apron, which thus polluted may injure the prints that are afterward passed through the dryer.

302. Ferrotyping.—Ferrotyping is a mechanical process for producing high gloss on prints. Only prints on paper having an enamel or glossy surface can be ferrotyped. The principle of ferrotyping is that when the emulsion side of a wet print is pressed into close contact with a smooth surface, the fibers of the gelatin of the emulsion are compressed in drying causing an increase in the gloss of the print.

a. Ferrotype plates.—For many years, ferrotype plates have been made of sheet iron coated on one side with a layer of enamel which is baked at high temperatures. A more recent type ferrotype plate is merely a sheet of stainless steel which is highly polished on both sides.

(1) *Care.*—Both types of ferrotype plates should be handled with extreme care to avoid scratches. The plates should be stored in grooves in cabinets and never allowed to touch each other or any hard surface. When cleaning or polishing the stainless steel plates,

they should be placed on a blotter or cardboard since they are finished on both sides.

(2) *Cleaning enameled plates.*—Using a mild soap, wash plates in soap and water whenever they appear dirty. How frequently they should be washed depends upon the cleanliness of the water used for washing, the number of times they are used, and the cleanliness of the location in which they are used. Usually washing every 3 or 4 days is sufficient. After washing, the plates should be rinsed and polished. The polish, which consists of paraffin dissolved in benzene, is applied to the plate with a soft cloth. The benzene cleans the plate and the paraffin fills the pores and any minute scratches which might be on the plate. The surface should be polished by rubbing briskly with a clean cloth. Enameled ferrotype plates should not only be polished in this manner after having been washed in soapsuds, but also every fourth or fifth time they are used. Each time before prints are placed on them, they should be rinsed in clean, warm water.

(3) *Cleaning stainless steel plates.*—Stainless steel ferrotype plates should be washed in soapsuds in the same manner as the enameled plates. They should also be washed in warm water each time before they are used. It is not necessary, however, to polish them with any polishing solution.

(4) *Removing print indentations from enameled plates.*—The enamel coating of ferrotype plates is often not so hard as it should be. When prints are placed on plates of this quality, they will become slightly embedded in the enamel. When the prints are dry, a countersunk imprint will remain in the enamel. This can be removed by leaving in water of near boiling temperature for about 1 minute. If this does not remove the defect, the process should be repeated.

(5) *Placing prints on the plates.*—As a rule, prints to be ferrotyped are treated in a softening bath before they are placed on the ferrotype plates. This treatment causes the prints to have a higher gloss and makes them more pliable.

(*a*) When ready to ferrotype a print, dip the plate into water to remove dust and lint. Lay the wet print face down on the ferrotype plate, holding it by the two diagonally opposite corners so as to form a loop. Bring the bottom of the loop into contact with the plate and then lower each corner until the print lies completely on the plate. Squeegee the surplus water from the tin and roll the print into contact with a print roller, first laying a blotter over the print to absorb the surplus water. The print must be in perfect contact to produce a uniform glossy surface. The pressure on the roller should be just sufficient to exclude any air bells that may form between the print and the plate, as heavy pressure is likely to make the prints stick in spots. In rolling, work from the center of the print toward the edges. If a quantity of prints is to be made, the tins can be run through a wringer, thus saving the labor of squeegeeing and rolling, and also saving many blotters as blotters are unnecessary when the wringer is employed. The print wringer, which is similar to an ordinary clothes wringer, is sometimes powered with an electric motor. A set screw on each side of the upper roller can be used to control the pressure required. In passing the plates and prints through the wringer, care must be taken to see that the roller does not wrinkle the prints. When a stainless steel ferrotype plate is used, one side is covered with prints which are pressed into contact. Prints are then placed on the opposite side and contact secured by running the plate through the wringer a second time. The plate is set in a suitable place to dry the prints, preferably in a drying cabinet as shown in figure 71.

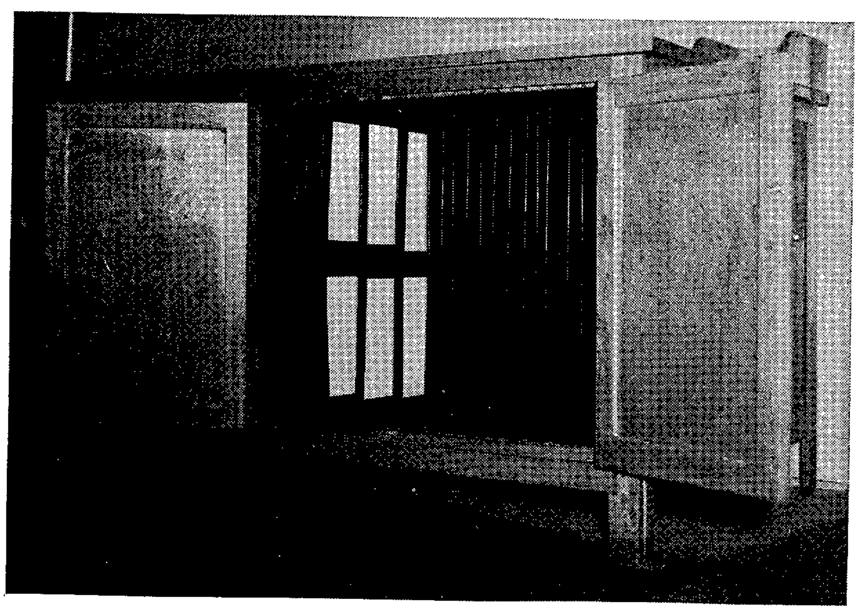


FIGURE 71.—Drying cabinet for ferrotyped prints.

(*b*) If the foregoing directions have been strictly complied with, the print will completely separate itself from the plate when it becomes dry. To remove a print from the plate that does not loosen and fall off, slip a piece of old film from a film pack under the edge of the print. This piece of celluloid will not scratch the tin. It is, therefore, preferable to the use of the fingernail. A knife blade should never be used.

(*c*) If the ferrotyped prints are to be trimmed, it should be done immediately after they leave the plates, and after trimming, they should be placed under pressure. Any tendency of the prints to curl may be greatly lessened by dampening the backs with alcohol and placing between blotters. Mosaic prints or copies of mosaics should not be ferrotyped as distortion may result.

(*d*) One of the difficulties encountered in ferrotyping is the sticking of the prints to the plate. This is caused by using dirty plates, the emulsions of the prints being too soft, or attempting to dry the prints in too much heat. A second difficulty is having drying rings (sometimes called "oyster shell markings") on the prints when dry. These are caused by part of the print drying in advance of other parts. The dried section becomes detached from the plate, contracts, and pulls an adjoining area away from the plate before this adjoining area is perfectly dry. This section then dries, contracts, and the process is repeated. These drying rings occur more often with double-weight than with single-weight prints. They are caused by too rapid drying. The method of prevention is to slow down the rate of drying, especially in the first part of the drying period. A second remedy is to dampen slightly the backs of the prints after they have dried for a few minutes. This prevents the backs of the prints drying before the emulsion has dried sufficiently to adhere closely to the plate. This dampening of the backs of prints being ferrotyped must always be practiced when the prints are on double-weight stock.

b. Machine ferrotyping.—(1) Several models of print dryers are manufactured which can be used for ferrotyping prints. In using a dryer of this type, the prints are placed emulsion up on a moving apron. This apron carries the print around a highly polished, heated, and slowly revolving drum. The apron holds the print in close contact with the drum until it sticks to the drum of its own accord. When the print has traveled one revolution around the drum, it will either fall off or is sufficiently dry that it can be easily removed from the drum.

(2) These machine ferrotype dryers have a capacity for drying many prints per hour. Good results are obtained when the gelatin of the prints is properly conditioned and the drum is kept clean and well-polished.

303. Straightening.—*a. Necessity.*—Because of the shrinking of the gelatin, most prints are curled and cupped when drying is completed. The print must be straightened before it can be accurately trimmed, properly mounted, or before it should be delivered in case it is not mounted.

b. Methods.—(1) A simple method of straightening a print is to place it, emulsion down, on a blotter and draw it underneath the straightedge in a manner that the print assumes a V-shape. The straightedge is drawn across the print at the same time. This method is quite satisfactory but is slow.

(2) Print straighteners utilize the above principle. The prints are drawn by motor-driven rollers or flexible belts across a V-shaped edge, the prints being bent away from the emulsion side as they pass across the V-shaped edge. Good results are obtained when the emulsions of the prints are not too brittle. Brittle emulsions, especially those of glossy prints, will crack when straightened in these machines. When it is discovered that the emulsions of prints are too brittle for straightening, the prints should be soaked in water, run through a glycerin bath, and redried.

(3) Although a somewhat slow method, the best way to straighten prints is to dampen the backs lightly and place between cardboards in a press. Prints should be left in the press for at least an hour. To conserve space, prints of the same size can be placed back to back between the cardboards. Even more space can be conserved by dampening the back of every other print and placing the back side of a dry print squarely in contact with the dampened side of another print, and dispensing with the cardboard. Only prints of one size are placed in one pile in the press. This method, however, is not so good as the use of cardboard.

304. Trimming.—A photographic print is trimmed to obtain a clean-cut edge, make width of borders uniform, reduce to desired size, and to improve composition.

a. The clean-cut edge of the paper often becomes roughened or frilled during its passages through the processing solutions. The appearance of the print is greatly improved by having a clean-cut edge.

b. Small prints when bordered are trimmed so the width of the white margin is equal on all sides. This margin may vary in width from 1/8 to 1/4 inch according to the size of the print. For example, the usual 1/2-inch masked border of an 8- by 10-inch print is trimmed to 1/4 inch. In the case of large prints, the borders may be uneven for artistic effect. The sides of the print are of equal width, while the top border is a little wider than the sides and the bottom border the widest of all.

c. Prints are trimmed to a specific size for the purpose of mounting, framing, or to match the size of other prints.

d. Composition of prints can often be improved by proper trimming. The point of interest should not have a mass of extraneous surroundings that might be distracting. An excellent method of judging the proper composition to which a print should be trimmed is to use two L-shaped pieces of cardboard. These are placed on the print and adjusted to form different shapes and sizes of rectangles, acting as frames to show the effect that would result if the print is trimmed to a particular size.

305. Equipment for trimming.—Equipment used for trimming prints are print trimmers, steel straightedges, and metal forms.

a. Print trimmer.—A print trimmer is essentially a flat surface of wood or metal fitted with a pivoted cutting blade. The blade is adjusted by a spring tension bolt to make contact with an accurately ground steel edge along one side of the trimmer. The flat surfaces of trimmers that will accommodate paper sizes as large as 30 inches wide are generally wood to conserve weight and expense, while the smaller sizes are of all metal construction. A measuring scale graduated in inches along the top edge of the trimmer serves as a guide for the paper. Some trimmers are marked with rule spacing on the flat surface, and in addition are provided with a transparent line guide along the cutting edge. This line guide serves the dual purpose of assisting in spacing the width of the border and also as a pressure plate to hold the print firmly when cutting. A print trimmer should not be used for cutting cardboard.

b. Steel straightedge.—For trimming large prints, either wet or dry, a steel straightedge and a sharp knife or razor blade for cutting are used. To prevent dulling the blade, a soft metal medium such as a sheet of zinc should be placed under the cutting edge. The print should be marked at each end with a pencil dot to guide the placing of the straightedge.

c. Metal form.—A metal form is used when it is desired that trimmed prints be oval or circular in shape. The form, usually brass, must be carefully cut or machined to the required size. A special cutting instrument is used, consisting of a sharpened steel wheel which is mounted in a swivel on the end of a handle. It is essential that the form be securely held in position while the cutting wheel is being moved around the circumference of the form.

Section V

MOUNTING PRINTS

306. Purpose.—Photographs are mounted to improve their appearance and to assist in their promotion. Their appearance is enhanced only when the print is properly spaced on a mount of proper color, texture, and size. The permanency of the photograph is assured only when the material used for the mount is chemically pure and the adhesive used is one which will not, in time, stain the mount or print.

307. Materials used.—Cardboard is the material most often used for mounts. Since ordinary cardboard often contains chemicals which are injurious to photographs, the cardboard used should be a type manufactured especially for mounting photographs. Photographs are also mounted on paper, cloth, glass, wood, and metals.

308. Cardboard mounts.—*a. Color.*—The color of the mount should harmonize with the color of the print. Black and white prints are usually mounted on gray mounts, but black or white mounts are also suitable. However, black mounts are unattractive and white mounts are undesirable because they are easily soiled. Prints made on buff or cream paper appear well on buff or cream-colored mounts. This applies to both black and white prints and to those which have been sepia-toned. Ordinarily sepia prints are mounted on brown- or tan-colored mounts. A popular color for a mount is called "neutral," which is suitable for either black and white, or for sepia prints.

b. Texture.—The texture of the mount and print should harmonize. For example, it would not be correct to mount a print having a smooth or glossy surface on a mount having a rough texture, nor could a print having a rough surface be correctly mounted on a smooth surface.

c. Ornamentation.—Many manufactured mounts are highly decorated with lines and scrolls. These decorations are usually embossed in silver on mounts for black and white prints and in gold when the mount is to be used for sepia prints. Mounts often are finished with beveled or deckled edges. While a certain amount of decoration in a mount will often improve its appearance, too much ornamentation will detract attention from the photograph.

d. Size.—(1) While there is considerable latitude allowable in the size of mounts in relation to the size of the print, there are certain rules which ordinarily apply and good judgment must be used.

(2) The mount should be large enough to balance and to appear as amply supporting the photograph. If the mount is too small, the impression of skimpiness is given; if the mount is too large, it belittles the print and the print appears as lost.

(3) While no definite rules can be given, a print 5 by 7 inches may be placed on a mount 8 by 10 inches in size. This will give a 1½-inch border. An 8- by 10-inch print should have not less than a 1½-inch border, and usually will appear better if mounted with a 2-inch border. Prints 16 by 20 inches should have at least a 2-inch border, but often a 3-inch border will give a better effect.

(4) Wider borders can be used if the borders are broken up with lines, scrolls, or other embossing.

e. Spacing of prints.—(1) The correct spacing of a print on a mount is of extreme importance, particularly if wide borders surround the print.

(2) The ideal spacing is to have equal margins on the sides, a trifle wider margin at the top, and a still wider margin at the bottom. An example of the above spacing is mounting vertically a 7- by 9¼-inch print on a 11- by 14-inch mount. The spacing should be 2 inches on each side, 2¼ inches at the top, and 2½ inches at the bottom.

(3) The above rules for the spacing of prints on mounts apply equally to prints which are mounted vertically or horizontally. When the margins of the mount at the top and bottom of the print are equal, the bottom margin will appear narrower giving the impression that the print is slipping from the mount. For this reason, the lower margin of the mount is usually wider. However, when the margins of the mount are narrow, it is permissible to center the print on the mount.

(4) Many prints, especially enlargements, are trimmed so that the bottom border is wider than those of the sides or top. When such prints are mounted, proportionate spacing should be used when affixing the print to the mount.

309. Adhesives.—While there are many substances which may be used as adhesives for mounting photographs, they may be classified as photo paste, glue or mucilage, rubber cement, gum arabic, and dry mounting tissue.

a. Photo paste is a white paste of which dextrine is the chief ingredient. It is very similar to library paste. Under this heading may be included flour and starch paste, as it is applied similarly and used for identical purposes.

b. Glue or mucilage is manufactured respectively from animal and vegetable products. These two adhesives are seldom used for mounting photographs except for what is known as the "tipping on" method. This means that the edge of the print only is fastened to the mount by applying a small amount of adhesive to the edge of the print.

c. Rubber cement is composed of unvulcanized rubber which has been dissolved in benzene. When two surfaces are coated with this adhesive and placed in contact with each other, this substance has great adhesive powers.

d. Gum arabic is mostly used for mounting mosaic prints. This adhesive is made by dissolving gum arabic (gum acacia) in water. The consistency of the solution is regulated by adding glycerin. Fermentation is avoided by adding salicylic acid.

e. Dry mounting tissue is in the form of sheets. It is manufactured by coating extremely thin tissue paper with shellac. When heat is applied to the tissue it becomes tacky, and when cooled is an excellent and permanent adhesive.

310. Use of photo paste.—Photo paste has disadvantages since it occasionally seeps out at the edges of the print and stains the mount, or the edges of the print fail to adhere to the mount. When photo paste is used, the following directions apply: Trim the prints to the desired size. Immerse in a tray of clean water, allowing them to soak long enough to become entirely limp. Remove them to a good-sized piece of clean glass or to a ferrotype plate, placing them in a pile, face down. Cover them with a piece of blotting paper and with a print roller or squeegee, press all surplus water from the pile. Then, with a good bristle brush about 1 inch in width and preferably one with hairs set in rubber, apply a thin even coating of the photo paste over the back of the uppermost print. It is immaterial, in the application of the paste to the top print, that it reach the backs of the underlying prints. Lift the print, turn it over, and lower it into place on the mount, holding it by diagonally opposite corners in a **U**-shape so that the middle comes into contact with the mount first. When the ends of the print are lowered, air will be excluded from between the print and the mount. When lifting the pasted print from the top of the pile, it should be touched as little as possible with the fingers. To place the print on the desired portion of the mount, use a guide which consists of a mask the size of the mount in which an aperture has been cut. This aperture should be in the correct position relative to the print and slightly larger than the print. As soon as the print has been laid upon the mount, lift the guide and place it to one side and then carefully and gently press the print into contact with the mount, using the fingers, a damp sponge, or a tuft of raw cotton, and working from the center outward so as to dispel any air from between the print and the mount. Remove any paste from the surface of the print. Then, with the print roller, roll into more perfect contact, at the same time removing with a piece of cotton any paste that may seep out from the edges. When the surface of the print is dry enough to cease to be sticky, place the print under weight or pressure until the paste is thoroughly dry so as to prevent the curling or warping of the mount. To insure that the print sticks properly to the mountant, the paste must be worked into the paper thoroughly and the edges and corners of the print well-pasted. The thinner the paper, the more easily it can be attached to the mount. Success in mounting double-weight paper demands that the paste have excellent adhesive qualities, that the print be properly dampened, and that the paste be fully worked into the dampened and thus open pores of the paper.

311. Mounting with rubber cement.—*a. Advantages.*—The advantages of rubber cement as an adhesive are:

(1) It works well in mounting either single-weight or double-weight prints.

(2) Ferrotyped prints can be mounted without loss of gloss.

(3) It is efficient for any temporary mounting such as to hold a print flat for copying or for temporarily mounting a print on or beside another print for copying.

b. Disadvantages.—The disadvantages of rubber cement as an adhesive are:

(1) It is messy to use.

(2) It is not very permanent.

(3) Sometimes it will stain both print and mount.

(4) Being inflammable, it is a fire hazard.

c. Directions for use.—A layer of cement is applied to both the back of the print and to the surface of the mount on which the print is to be placed. If the margins of the mount which will surround the print are not too wide, it is advisable to cover the entire surface with the cement. The cement should be applied quickly and uniformly by means of brush or fingers. When the cement is dry, the print is placed on the mount by placing one edge of the print in the exact position on the mount which it is to occupy. When it is evident that the spacing is correct, the remainder of the print is lowered and the complete print then pressed into close contact with a print roller. Any adhesive on the surface of the print or on the edges of the mount should be immediately removed by brushing with a cloth. The following precautions should be observed when using rubber cement in mounting:

(1) The coatings of cement applied must be sufficiently dry before the print is placed on the mount. Two or three minutes are usually sufficient, but a longer time will do no harm.

(2) The print must be placed at the first attempt in the exact position it is to occupy on the mount since it is impossible to shift it after the two surfaces of rubber cement have contacted each other. When necessary to change its position, the print must be taken from the mount and the cement removed from both the print and the mount, after which they must both be recoated. When mounting large prints, a piece of paper can be laid over all the mount except the area where the first edge of the print is placed. The paper can be slowly withdrawn, the print being pressed in close contact with the areas bared as the paper is withdrawn.

(3) The container in which rubber cement is placed should be kept tightly closed to prevent the evaporation of the solvent. When too thick, rubber cement can be thinned by the addition of benzene. Since rubber cement is explosive, it must be protected from fire hazards.

312. Use of glue and mucilage.—Glue and mucilage are seldom used in mounting except for fastening prints to mounts by the "tipping on" or "tacking" method. Even this method is practical only for double-weight prints since single-weight prints mounted in this manner are likely to pucker where the adhesive is applied.

313. Use of gum arabic.—A solution of gum arabic and water is sometimes referred to as gum arabic mucilage. It is generally used in an entirely different manner from glue and other mucilages. Gum arabic is seldom used in mounting except in laying mosaic maps. Its slow-setting properties and strong adhesive power after it has dried makes it most desirable for this type of work. Prints must be thoroughly fixed and washed, otherwise this adhesive may stain the prints yellow.

314. Disadvantages of liquid adhesives.—The use of liquid adhesives in mounting photographs is a sticky operation. The wetting of the prints, which this method requires, produces a surprising amount of expansion in the paper support of the print and this often upsets previous calculations made to place the print exactly in a certain position on the mount. The result of this expansion is a contraction of the print when drying, which is strong enough to warp even a heavy cardboard mount. While rubber cement may be applied to a dry print, it is not a satisfactory solution of the mounting problem as a print coated with it must be lowered exactly into position on the mount, and errors cannot be corrected afterward by moving it about even slightly. In time, the rubber in the cement hardens and disintegrates. The print then becomes detached from the mount.

315. Dry mounting.—*a. Advantages.*—The process of dry mounting overcomes the difficulties of the other systems. Dry mounting tissue is inserted between the print and the mount, and upon pressure of a hot iron, the heat liquefies the tissue sufficiently to secure the adhesion of the print to the mount. The advantages of this process, when compared with the use of liquid mountants, are obvious. Prints can be mounted dry without consequent curling.

b. Technique.—The main piece of equipment used in dry mounting is the dry mounting press of suitable size, which is electrically heated (fig. 73). If this is not available, a heated flatiron may be used, but this method is not practical when a large number of prints are to be mounted. Included with the press is an electrically heated tacking iron which closely resembles a soldering iron (fig. 72). Dry mounting tissue is furnished in packages of sheets cut to sizes corresponding with those of photographic paper. To use the tissue, place the print to be mounted face down and tack a sheet of the tissue on the back of the print. This piece of tissue should be of the same size as the print, preferably a little larger if the print is untrimmed. The tissue adheres to the back of the print by applying the point of the heated tacking iron or the point of a flatiron. The hot iron should be drawn a short distance across the print to give the tissue a firm hold. When mounting prints larger than 8 by 10 inches, they should be tacked in several places. This will hold the tissue in place so that a number of prints can be prepared in advance for mounting. The tacking iron will retain an even temperature. The flatiron should be just hot enough to sizzle when touched with a wet finger. If the iron is not hot enough, the tissue will stick to it. Turn the print face up and trim both the print and the tissue to the same size. This is facilitated when the prints are flat. Place the print in predetermined position on the mount, raise one end, and tack the tissue in place on the mount while holding the print in place with the left hand as in figure 72. This "tipping on" of the print to the mount is to prevent the slipping of the print when the complete contact of the print with the mount is being effected. The final operation may be performed either with a flatiron or in the dry mounting press. When a flatiron is used, cover the print with a piece of smooth paper, then press the whole surface with the heated iron. *Press, do not rub.* The flatiron should be at the same temperature as when used for tacking. If the iron is too hot, the tissue will stick to the mount. If it is not hot enough, it will stick to the print. When the dry mounting press is used, place the print on the bed of the press and cover with a sheet of cardboard. Press the platen into contact and allow the print to remain in the press for 25 to 30 seconds. Several small prints may be placed side by side in the press but not on top of one another. The temperature at which the dry mounting press should be used is readily determined by the manner in which the tissue is affected. With too little heat, the tissue will not stick. Too much heat will completely melt the tissue and the print will curl from the mount when removed from the press, as the excess heat prevents the tissue from setting. The print may be placed in the press again, however, with an extra piece of cardboard over it, and it will be mounted perfectly. The extra cardboard will reduce the heat and the tissue will then stick. A good rule by which the press may be brought to the correct temperature and remain so is to turn the current on "low" for 20 minutes before it is to be used. It will then retain the proper temperature. The correct time that the print should remain in the press is quickly learned by experience and the operator can readily plan the work so that prints may be in the press while others are being prepared. Prints larger than the press are easily mounted by making several impressions so that all portions of the print receive an equal application of heat and pressure, in which case the cardboard should be 1 inch larger each way than the press to avoid pressure lines.

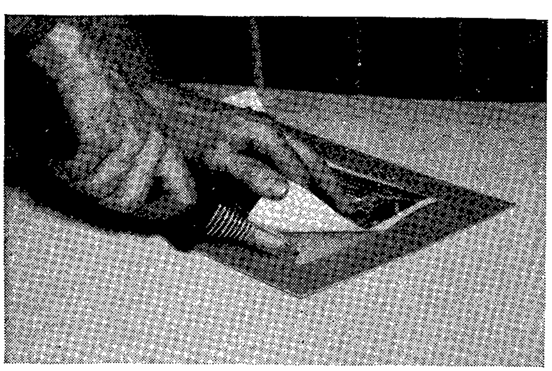


FIGURE 72.—Dry mounting tacking iron.

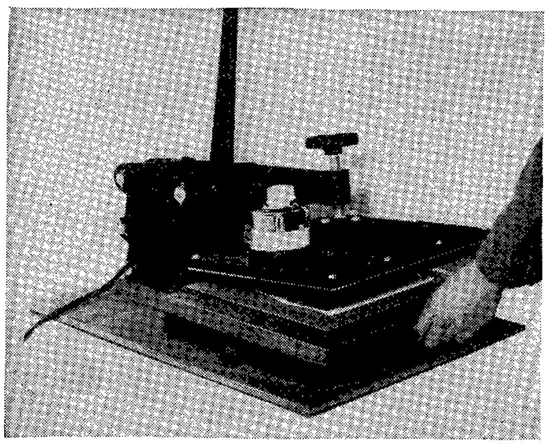


FIGURE 73.—Dry mounting press.

c. Failures.—(1) The dampness of mounts, or prints, is responsible for frequent failures in dry mounting. If the prints are damp, the gelatin will melt from the heat of the press and the emulsion surface will become sticky, while if the mount is damp, the heat of the press will cause it to warp. A print somewhat damp will also contract in the hot press, but the tissue will be unaffected and the result will be a narrow border of the tissue around the edges of the picture. If the finished result does not lie flat, the cause is generally due to the use of a mount that is both too damp and of spongy quality. The obvious remedy is to keep prints and mounts in a warm dry place an hour or two before beginning mounting operations, spreading the prints and mounts on a table, or otherwise exposing them freely to warm dry air.

(2) The failure of prints to stick is usually due to the fact that the temperature of the press is too low. About 150° F. is proper for prints on single-weight paper and 180° to 190° F. for those on heavier paper. If the press is heated from above, the platen is on top, then the mount face up, and the cardboard at the bottom. The incorrect placing of these items may mean lower effective temperature, since the cardboard is a poor conductor of heat.

(3) If the temperature of the press is 250° F. or over, the tissue remains in a melted state for some seconds after the mount is removed from the press and the print is likely to become detached from the mount when cool.

(4) Prints on double-weight paper may not adhere firmly to the mount due to the gelatin surface contracting in the press and

causing the print to curl away from the mount during the few moments while the tissue has not perfectly set on removal from the press. The remedy is to relax pressure just enough to keep the tissue in contact with both surfaces while it cools.

SECTION VI

PRINT DEFECTS

316. Abrasion marks or streaks.—*a. Cause.*—Friction on the emulsion of the paper due to improper storage or handling.

b. Remedy.—Sensitized photographic paper should always be handled with the utmost care. When cutting large sheets of sensitized paper to smaller sizes, place two sheets at a time, emulsion to emulsion, thereby protecting the sensitized surfaces from contact with the paper cutter. When removing a sheet of sensitized paper from the container, draw the sheet slowly with a slight upward pull. The paper should be kept on edge in a cool, dry storage place and never handled roughly. The addition of a small amount of potassium iodide to the developer (not exceeding one-eighth of a grain to each ounce of working solution) will generally eliminate abrasions. Use potassium iodide only when necessary.

317. Air bells.—*a. Cause.*—If bubbles of air form on the surface of the print during development thus preventing the solution from reaching the emulsion covered by them, white spots will result if the bubbles are formed in the developer, and discolored spots if formed in the fixing bath.

b. Remedy.—Immerse the sheet of paper in the developer with a sliding movement, emulsion side up, as quickly and as evenly as possible. Always have plenty of developer in the tray. Never develop or fix a print emulsion side down.

318. Bad definition; blurred spots.—*a. Causes.*—(1) Negative and paper not in perfect contact.

(2) In projection printing, bad definition can be caused by poor focusing, vibration, or excessive magnification.

b. Remedy.—(1) If the printing machine is fitted with a pneumatic lid or top, the air cushion must be sufficiently inflated. The air cushion should not be so inflated as to require undue pressure on the handle when making the contact. If the printer top is constructed with a felt or sponge rubber facing, the hinge must be adjusted to insure even pressure on the printer glass when the top is in printing position.

(2) Check focusing, make enlarger more stable or eliminate vibrations; do not enlarge negatives excessively.

319. Blisters.—*a. Causes.*—Anything that will cause a slight rupture of the emulsion surface may result in the formation of a blister.

(1) Softening of the emulsion caused by insufficient hardener in the fixing bath, thus allowing the gelatin to become separated from its paper base.

(2) Too great a change in temperature between the different processing baths.

(3) Allowing water to run directly on the print from the faucet with excessive force.

b. Remedy.—Do not allow water from a faucet to be directed on any one spot of the print. Use a correctly prepared acid hardening fixing bath. It is good practice to use two fixing baths, one to do the preliminary fixation and one fresh or slightly used to finish the process. Keep all solutions and water as nearly even in temperature as possible.

320. Blurred print.—*a. Cause.*—A print made from the back of a film negative will be slightly blurred. If only the edges of the print are blurred, the printing mask is too thick, thereby preventing proper contact between negative and sensitized paper.

b. Remedy.—The emulsion side of the negative must always be in perfect contact with the emulsion side of the sensitized paper, otherwise there will be a lack of sharp definition in the print and a reversal of direction in the subject, as between right and left. The material used for masking the negative should be thin black paper.

321. Brown spots and stains.—*a. Causes.*—(1) Rust from any cause coming into contact with the emulsion surface.

(2) Chemical dust in the laboratory settling on the surface of the paper.

(3) Rusting equipment used in processing.

(4) Exhausted or oxidized developer.

(5) Developing action being allowed to continue after it should be stopped.

(6) Weak acid content in fixing bath.

(7) Removing prints from developer and handling them too much before the developing action is stopped.

(8) Not using acid short stop or insufficient rinsing in water between development and fixation.

b. Remedy.—Obvious.

322. Fading tendency.—*a. Causes.*—(1) Incomplete fixation, resulting in light affecting the silver halide which has not been entirely removed from the emulsion.

(2) Prolonged immersion in a fixing bath that is nearing exhaustion and has become overcharged with silver.

(3) Insufficient washing, permitting hypo to remain in the emulsion. This action is gradual, but will be hastened in a damp climate.

(4) Using an overworked fixing bath makes it extremely difficult to wash prints free from hypo and other undesirable compounds.

b. Remedy.—(1) Allow prints to remain immersed in a fresh fixing bath at 65° F. for 5 to 7 minutes, for the first dozen 8- by 10-inch prints or equivalent in other sizes. From that point on, the fixing period should be advanced proportionately to 10 minutes until approximately fifty 8- by 10-inch prints have been fixed and then to 15 minutes until one hundred have been processed. This applies to 1 gallon of standard formula acid fixing bath. When the stated number of prints have been fixed in the bath, it should be discarded. The prints should be moved around in the bath sufficiently to insure that the solution comes into contact with the entire surface of each print.

(2) Prolonged immersion of prints in a fixing bath which is nearing exhaustion will result in the paper stock and emulsion absorbing some of the complex silver thiosulfates from the bath. Such compounds are very difficult to remove by washing and if not removed

may cause fading or staining of the print. The insertion of the print in a fresh hypo bath for about 5 minutes prior to washing will assist in the removal of these troublesome compounds.

(3) Wash prints longer according to the prescribed methods and use an adequate hypo test.

(4) Never overload a fixing bath with a larger number of prints than the bath can properly fix.

323. Finger marks.—*a. Cause.*—Wet, moist, or chemically contaminated fingers.

b. Remedy.—Handle all sensitized emulsions with dry, clean hands and never touch the surface of the emulsion. Great care should be taken to rinse the hands thoroughly so as to free them from any of the fixing bath or of any other chemicals with which they may have come into contact.

324. Flatness.—*a. Causes.*—(1) Use of wrong grade of paper for the particular negative. The print has a dull gray appearance over its entire surface, showing insufficient distinction between tones.

(2) Overexposure and underdevelopment.

b. Remedy.—Change to a grade of paper that will give a greater degree of contrast.

325. Fog.—*a. Causes.*—(1) Using a safelight, the light of which is actinic to the emulsion.

(2) Light-struck paper.

(3) Paper that has passed the expiration date of the emulsion.

(4) Paper improperly stored, so that the container in which it is packed has been exposed to chemical or paint fumes.

(5) Prolonged development beyond the specified time. This practice is known as forcing resulting in a reduction of the silver halide not affected by light during the exposure.

(6) Improperly prepared developer, such as impure chemicals, insufficient potassium bromide, etc.

b. Remedy.—(1) Test safelight. See that safelight is not closer than the working distance for which it is intended. Do not unnecessarily expose the paper for too long a time to safelight.

(2) Keep unexposed paper in light-proof container in the presence of white light. While printing, remove only the sheet of paper required for use, from the container. Do not remove paper from its wrapping, slit one end and use this as an envelope.

(3) Paper that is appreciably past its expiration date should be discarded.

(4) Keep all stored emulsions free from the fumes of chemicals, fresh paint, and the penetrating action of X-rays.

(5) Avoid wasting time by prolonging or forcing development of an underexposed print.

(6) Mix developers carefully. Store chemicals in a cool dry place, discard deteriorated chemicals, use chemicals of standard and known purity and see that the weighing scale is in balance.

326. Freaks.—*a. Cause.*—Uneven development. Developer too warm, too weak, or working solution not thoroughly mixed.

b. Remedy.—Keep print moving during development usually by rocking the tray with an irregular motion. Maintain the correct working temperature of the developer. Developer loses its strength with use; do not overwork it. When the solution becomes cloudy or turns a brownish color, discard it. Mix the working solution thoroughly by stirring the stock solution in the correct amount of water. Ripen all fresh working developer either by developing three or four sheets of exposed paper or retaining 25 percent of used developer to mix with the fresh bath.

327. Frilling.—When an emulsion becomes loosened (generally at the edges) from its supporting base, the curling back effect produced is termed "frilling."

a. Causes.—(1) Careless handling.

(2) Solutions too warm.

(3) Fixing bath weak or lacking a sufficient amount of acid hardener.

b. Remedy.—(1) Do not unnecessarily handle the prints while in the developer. Grasp the print only by its edge when removing it from the developer.

(2) Maintain all solutions at correct temperature. If extremes of temperature are encountered, place the working developer tray in a water bath.

(3) It is important that the fixing bath is in proper condition and contains sufficient acid hardener. The simplest method of maintaining proper fixation is to use two fixing baths as previously explained.

328. Grayish or granular appearance of borders of print.—*a. Causes.*—(1) Underexposure and forced development.

(2) Old or expired paper.

(3) Moisture.

(4) Chemical fumes.

(5) Light fog.

(6) Insufficient amount of potassium bromide in the developer.

b. Remedy.—(1) Expose print so that it will develop to the proper density in the stipulated time.

(2) Discard paper which is long past expiration date.

(3) If paper is kept in block form, moisture present will affect the edges first. Keep unused paper in container and in the moisture-proof wrapping as packed by the manufacturer.

(4) Have only supplies of paper required for immediate use in the laboratory. Sensitized paper is particularly affected by sodium sulfide and turpentine fumes.

(5) Be sure paper is properly protected before turning on white lights.

(6) The amount of potassium bromide in formula used must never be less than that prescribed.

329. Greenish-brown tones.—*a. Causes.*—(1) Exhausted developer.

(2) Developer diluted too much.

(3) Too low a temperature of developer.

(4) Overexposure and underdevelopment.

(5) Excessive amount of potassium bromide, or anything that retards action of the developer.

(6) Contamination of developer, usually from hypo.

(7) Acid in the developer.

b. Remedy.—(1) Do not develop a larger number of prints than the amount of the developer will handle properly. For example, when using 48 ounces of working developer for 8- by 10-inch prints, examine prints carefully after the first 12 have been put through, for change in tone. The first and last print developed should be carefully compared in daylight.

(2) Use only the dilution of working developer that the stock solution calls for. When the regular dilution does not produce pure black tones, it is due to error in mixing the stock solution or use of impure chemicals. In such instances, the working developer should be strengthened or a fresh batch of stock solution correctly mixed.

(3) Maintain correct working temperature of solutions. A low temperature has a retarding action on the developing process. If the development time is 1 minute at normal temperature, more development must be given if the temperature of the developer is below normal to bring the print to the desired density.

(4) Both correct exposure and correct development are essential in producing satisfactory results.

(5) Too much bromide in developer. An insufficient amount of carbonate, a cold or weak developer or anything that tends to retard the action of the developer, will produce unsatisfactory tones. When the formula for the working developer solution calls for additional potassium bromide, as in the processing of some bromide and bromo-

chloride papers, the excess potassium bromide is usually added in drops from a saturated solution of this chemical at the time the working solution is prepared.

(6) If the hands have come into contact with the hypo fixing bath, care must be exercised that the developer is not contaminated from this source.

(7) Acid is also a form of contamination that must be kept out of the developer.

330. Muddy tones.—*a. Causes.*—(1) Overexposure.

(2) Insufficient development.

(3) Dampness.

(4) Exposure of paper to chemical fumes.

b. Remedy.—(1) Determine exposure after test and time accurately.

(2) Develop print for correct time. Generally, if the development of the print is carried beyond the stipulated time, the colder will be the tone. Eventually, prolonged development will produce chemical fog.

(3) Store paper in cool dry place.

(4) Keep supply free from chemical fumes.

331. Prints too dark.—*a. Causes.*—(1) Overexposure.

(2) Overdevelopment.

(3) Overexposure and overdevelopment.

(4) Insufficient bromide in developer resulting in too rapid development.

(5) Wrong grade of paper for the degree of contrast in the negative.

b. Remedy.—When cause has been determined, the remedy will be self-evident.

332. Prints too light.—*a. Causes.*—(1) Underexposure.

(2) Underdevelopment.

(3) Underexposure and underdevelopment.

(4) Paper selected is not within gradation scale of the negative.

b. Remedy.—Determine cause and make new print.

333. Purple discoloration.—*a. Causes.*—(1) Improper fixation.

(2) Failure to move prints sufficiently during first 2 minutes in fixing bath.

(3) Not completely immersing prints in fixing bath.

(4) Allowing prints to float, emulsion side up, on top of the fixing bath.

b. Remedy.—On completion of development, remove surplus developer from print quickly but thoroughly in a plain or an acid rinse bath. Immerse print completely in the fixing bath. Keep all prints in motion for the first few minutes in the fixing bath. Do not allow prints to float emulsion side up on top of bath. After the first few minutes, the prints may be turned over (emulsion side down) provided no air bubbles remain caught on the emulsion surface.

334. Uneven development.—*a. Causes.*—(1) Improper immersion of print in the developer.

(2) Developer not continuously agitated.

b. Remedy.—(1) Immerse the exposed paper entirely and quickly in the developer.

(2) Keep print immersed and rock tray with an irregular motion during the entire development time.

335. Uneven fixation.—*a. Causes.*—(1) Failure to move prints frequently while in the fixing bath.

(2) Prints sticking together.

(3) Air bells on surface of print (rare).

(4) Prints floating on surface of fixing bath.

b. Remedy.—(1) Move prints frequently to insure chemical action on all areas of the emulsion surface.

(2) Keep prints separated in fixing bath, especially during first few minutes.

(3) Avoid any handling which might cause air bells.

(4) Parts of a print floating on the surface will generally be exposed to the air, in which case the exposed part will not receive the full action of the fixing bath.

336. Weak prints.—*a. Causes.*—(1) Underexposure.

(2) Bleaching. Most noticeable in highlights.

b. Remedy.—(1) Make new print giving more exposure.

(2) Fix prints for specified time. Prints will bleach in the fixing bath if fixation is prolonged beyond the correct time.

337. White deposit on surface of print.—*a. Cause.*—If the fixing bath shows a milky appearance, it has become sulfurized and is useless, showing a white deposit on the surface of the print.

b. Remedy.—Prepare fresh fixing bath, correctly using chemicals of known quality and purity.

338. Spots (white).—*a. Causes.*—(1) Small irregular spots caused by particles of dust, dirt, or fragments of paper from the edges of the sensitized stock adhering to the negative will leave white spots on the print.

(2) Dust or dirt on the glass top of the printer.

(3) Air bells.

b. Remedy.—(1) Keep negative clean. Remove particles by tapping or blowing. If the negative is wiped or brushed, it will become electrified and attract small objects to its surface.

(2) Keep printer top glass clean.

(3) For air bells, as described in paragraph 317.

(4) Remove any remaining white spots on prints by retouching and spotting process.

339. Spots (black).—*a. Cause.*—Print made from negative that has unretouched pinholes.

b. Remedy.—Spot out pinholes in the negative before printing. The black spots may be bleached out of the print by applying a small amount of tincture of iodine applied with a fine brush or sharp-pointed stick of wood, after which the print is placed in fixing bath for a few minutes and then washed. The black spot is changed to a white spot which may be retouched in the usual manner.

340. Yellow stains (sometimes brownish-yellow).—*a. Causes.*—(1) Weak or exhausted fixing bath not properly stopping action of the developer.

(2) Weak or oxidized developer, or forcing development will frequently produce yellow oxidation stains.

(3) Failure to rinse prints properly between development and fixation will generally cause stains by allowing the surplus developer to continue its action in the fixing bath.

(4) Uncleanliness, poor processing methods, causing the developing solution to become contaminated.

(5) Hypo carried into the developer will result in a retarded action causing stains similar in appearance to forcing the print. It will also degrade the whites as well as other tones.

(6) Insufficient washing. The permanency of good print tones is mostly dependent upon the complete removal of all chemicals in the final washing, thus preventing the yellow fading tendency.

(7) Examining a print by white light before being fixed sufficiently to prevent further reduction of the silver halide.

(8) Prolonged exposure of a print in the humid salty atmosphere of the ocean.

b. Remedy.—Obvious.

CHAPTER 11

COPYING

SECTION I

GENERAL

341. Definition.—The term "copying" as used in photography means the photographing of another photograph, a drawing, map, or similar flat object.

342. Necessity.—An original negative may not be available, thus necessitating the making of a new negative from a print.

SECTION II

MOSAIC COPYING

343. General.—The photographic reproduction of mosaics is required for the purpose of mass production or a change of scale. Often several mosaics of the same area are required and it is easier and quicker to assemble one mosaic and reproduce it than it would be to make more than one from the original negatives.

344. Original print and emulsion required.—Experience has proved that it is easier to reproduce a mosaic composed of prints that are a little flat and of normal density than one made of prints of more than normal contrast. Any negative emulsion of moderate speed and contrast is satisfactory. Since mosaics are generally not colored, a color-blind or orthochromatic sensitivity is most desirable.

345. Lighting.—The area to be covered by each exposure is considerably larger than that required in average copying, so particular care must be exercised in lighting the subject. All parts of the mosaic not included by the individual exposure should be covered with some light-absorbing material to prevent reflections directly into the lens. (See fig. 74.) The lens board should be similarly treated unless it has a dull matte surface of low reflecting ability. The use of polarizing filters materially aids in the elimination of reflections. (See fig. 75.) Unless polarizing filters are available it is essential that the light source be so placed that the light incident upon the subject is not reflected directly into the lens. In placing the light and directing it toward the subject consideration must be given to the fact that the angle of reflected light is equal to the angle of the light incident upon the material (fig. 76).

346. Placing.—The mosaic should be so placed on the camera easel that the image will be centered on the focusing screen when the screen and lens are in their respective normal positions. Deviations from these positions must never be so great that the image or any part thereof will fall outside the acceptable circle of illumination. The mosaic and focusing screen must be parallel to each other and in a plane perpendicular to the lens axis. Improper arrangement will result in an image of uneven scale.

347. Developing the film.—It is imperative that mosaic copy negatives receive the same degree of development to insure equal printing qualities. Large-size negatives are usually developed singly and in a tray. Unless a developer is used which does not easily oxidize, it is necessary to increase the time of development of the second negative to insure equal development. If the copy work is composed of three large negatives, additional development time must be allotted to the third negative. If more than three negatives are to be processed, not more than two should be developed in a batch of developer. Mosaic copy negatives should overlap one another about 1 inch. When printing these negatives, the prints must therefore be matched within this small area. A high degree of accuracy of development is necessary to insure negatives which will produce prints of equal contrast.

348. Copying to scale.—The scale of a reproduction is the ratio between any given dimension on the original and a corresponding dimension on the reproduction. For example, if an 8- by 10-inch picture is reproduced at half scale, it would be 4 by 5 inches in size and contain an area of 20 square inches. An 8- by 10-inch print copied at half size would contain 40 square inches, or one-half the original area. Size, therefore, pertains to area.

a. To determine the dimensions of a copy when a definite size is stated, apply the following formula: The square root of the original area is to the square root of the required area as one side of the original is to the corresponding side of the copy. The other side of the copy is found in the same manner, using the corresponding side of the original in the proportion.

Example: Copy an 8- by 10-inch print to contain one-half its area, or 40 square inches.

$$\sqrt{80}:\sqrt{40}::8:x$$

and

$$\sqrt{80}:\sqrt{40}::10:x$$

The results indicate the dimensions or size of the copy which, when multiplied together, indicate the area.

b. Some copying cameras are equipped with a mechanical device to be used for quick adjustment to a particular scale. The operation involved is simply to set the device to a predetermined setting. The scale settings indicate the camera bellows extension and the distance from the lens to the subject which are determining factors of scale.

(1) Cameras not made for copying may be calibrated with scale settings. The following formula is applicable to approximate conjugate distances at any desired scale: The focal length of the lens multiplied by the scale, plus 1, is the approximate distance from the focal plane to the lens. This distance divided by the scale of the copy equals the approximate distance from the lens to the easel on which the subject is placed.

Let

$$f = \text{focal length}$$
$$sc = \text{scale of desired copy}$$
$$f(sc+1) = \text{distance from lens to focal plane}$$
$$\frac{f(sc+1)}{sc} = \text{distance from lens to subject}$$

To adjust the camera to one-half scale with a 12-inch lens, the following substitutions are made in the formula:

$$12\ (\tfrac{1}{2}+1) = 18 \text{ inches, distance from lens to focal plane}$$
$$\frac{12\ (\tfrac{1}{2}+1)}{1/2} = 36 \text{ inches, distance from lens to easel}$$

The distance from the front to rear surface of the lens varies with different lenses, therefore this computation indicates only approximate results. It is used to approximate the distance of the focal plane and the easel relative to the lens, but for accurate scale, actual dimensions of the copy must be checked by measurement on the focusing screen, followed by rechecking of measurements on the negative after processing.

(2) If conjugate distances cannot be measured and the camera is not equipped with a scaling device, measurements of the image must be made on the focusing screen to adjust the camera to a particular scale. This is accomplished as follows: Determine the scale to which the copy is to be made as compared with the scale of the original. Measure a distance between two points on the original and determine what this distance should be on the copy. Cut a piece of paper to measure exactly this computed distance. Move the camera to approximately the required distance from the subject to make the copy at the required scale. Visually focus the camera. If lighting conditions or the contrast of the original are such that focusing is difficult, the substitution of printed matter of high black and white contrast will materially aid in this operation. By trial and error, move and focus the camera until the distance between the image points complies with the computation. This distance should be measured by means of the paper which represents it. Care should be exercised when measuring the image distance that the reading is taken perpendicularly to the focusing screen.

349. Mosaic copying in the field.—Mosaics may be satisfactorily copied under field operating conditions. If copied out-of-doors, the apparatus should be set up in the shade to avoid troublesome reflections.

Section III

CAMERA

350. Type.—Any camera which is capable of taking a picture can be used for copying, but not so satisfactorily as a camera especially designed for the purpose.

351. Bellows.—A camera of this type should be capable of a bellows extension of at least three times the focal length of the lens used. This will permit a two times enlargement of the subject copied. The bellows should also be readily collapsible to the equivalent of one focal length so as to permit any scale of reduction of which the lens is capable.

352. Construction.—For convenience, the camera should be so mounted that the ground glass is parallel with an easel which accommodates the subject matter and is an integral part of the camera construction. It is also important that the lens axis be perpendicular to the ground glass and easel. A camera so constructed will produce images as true to scale as the accuracy of the lens will permit. If a camera is used which is not designed for copying, the operator must carefully adjust his apparatus to meet the above specifications if true scaled images are desired. A simple and accurate test of determining the parallelism of easel and ground glass is to focus on a sharply defined square, preferably drawn with black ink. Unless the image of the square is in true proportion to the original, either the easel and focusing screen are not parallel or the lens axis is not perpendicular to these surfaces. Assuming the lens to be in its correct position, the operator should adjust the easel and camera until the desired effect is produced on the focusing screen.

353. Lens.—The copying lens should be ground to a flat field, fully corrected for all aberrations, and capable of perfect definition over the entire area to be covered. A lens with these qualifications is known as a process anastigmat. It is designed for work at a short distance from the subject matter and is slow in speed, rarely being faster than *f*/8. It is desirable, but not essential, that the copying lens also be apochromatic, since some reproduction work is the reproduction of color.

Section IV

TECHNIQUE

354. Selection of emulsions.—Emulsions of all classifications with regard to color sensitivity are used in ordinary copy work, that is, color-blind or orthonon, orthochromatic, and panchromatic. Following is a list of typical subjects and the emulsions best used to reproduce them:

a. Black and white line drawings, use a color-blind process emulsion.

b. Colored-line drawings (containing colored lines other than blue) on a white ground, use a color-blind process emulsion.

c. Colored-line drawings containing blue to be rendered as black, use a process panchromatic emulsion in conjunction with a blue absorbing filter.

d. Line drawings on a colored background should be photographed with a process panchromatic emulsion in conjunction with a filter which transmits the color of the background, unless the background is a very light blue as in the case of tracing cloth, or a background similar to it. Such subjects will satisfactorily reproduce with a color-blind process emulsion.

e. Black and white prints with halftones may be copied with any emulsion of moderate contrast. If panchromatic materials are used, a filter is not necessary.

f. Colored prints with many colors, use an ortho-panchromatic emulsion with or without a filter, depending upon the result desired.

355. Lighting the subject.—*a. Artificial illumination.*—(1) Proper lighting is of prime importance in copying. An even distribution of light over the entire subject matter is generally best for the purpose. The light should be of such intensity that a suitable latitude of exposure time is possible. The lights should be so placed that an image of the source will not be reflected into the lens. The presence of troublesome reflections can usually be seen by viewing the subject from the lens position. A better way is to remove the lens and ground glass and view the subject through the camera. If it is

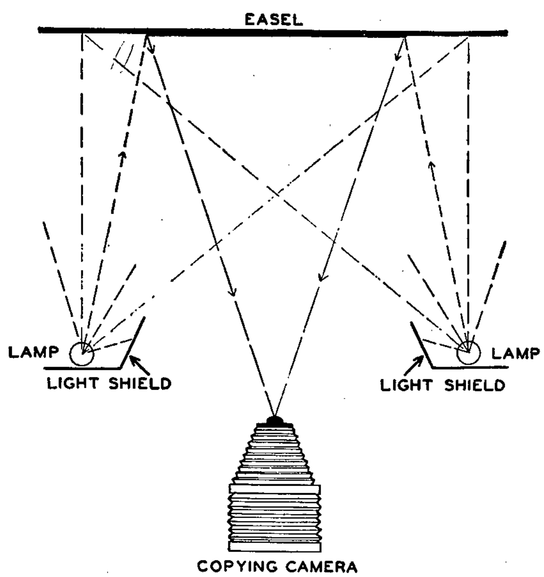
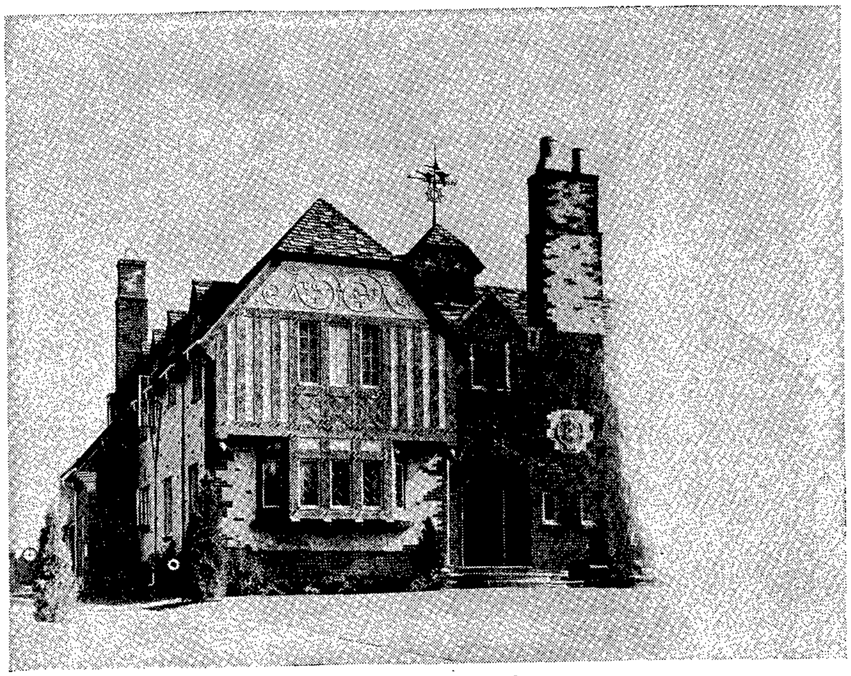
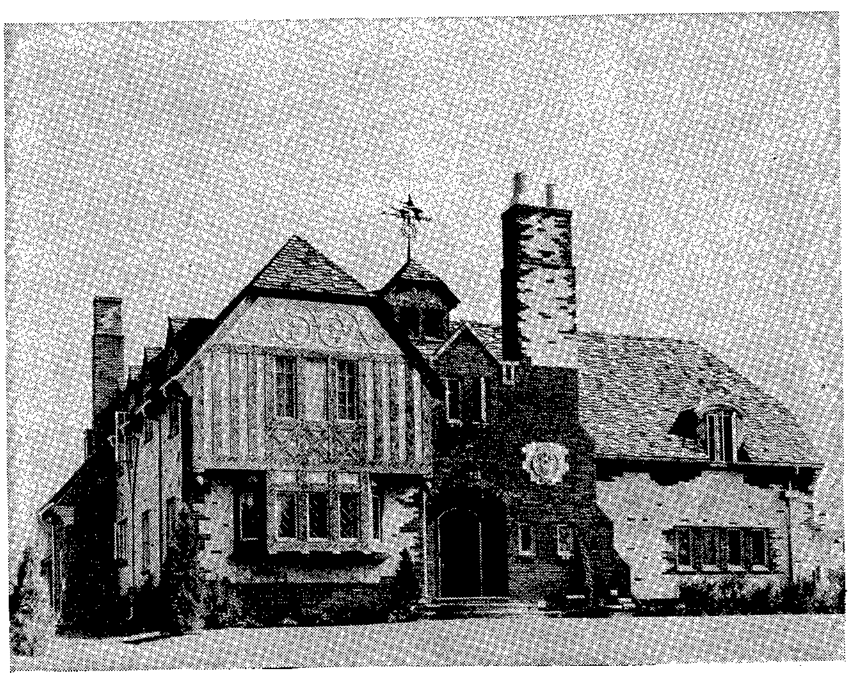


FIGURE 74.—Artificial illumination.



① Without polarizing filter.



② With polarizing filter.

FIGURE 75.—Effect of using polarizing filter.

impossible to remove all reflections by adjusting the lights, polarizing filters can be used to advantage. The ideal method of use is to place a large polarizing filter over each light source and another in front of the lens. By proper adjustment of these screens, reflections can almost be eliminated in most cases. If large polarizing filters are not available, two small ones may be placed in front of the lens. When these filters are properly adjusted, they will eliminate most but not all reflections if several light sources are used. (See fig. 75.)

(2) In rough surface originals, the lights should be placed as close to the side of the camera as operating conditions and the angle of reflection will permit, so as to eliminate the infinite number of shadows caused by the rough surface. *The use of a reflector is not recommended.*

b. Daylight illumination.—Daylight may be used in making copies but if used, it should be measured with a light meter because of its variable intensity. If the light passes through a window, the copying apparatus should be so arranged that the light will not fall directly on the subject. A reflector may then be used as an aid to proper illumination (fig. 76). Should the copying operations be undertaken out-of-doors, the apparatus should be set up in the shade to obtain even and diffuse illumination.

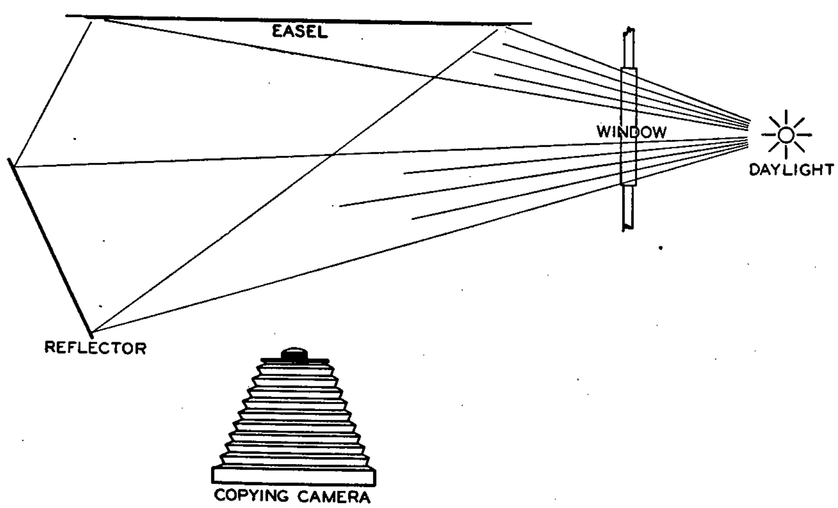


FIGURE 76.—Daylight illumination.

356. Exposure factors.—In calculating the exposure, consideration must be given to the following factors:

a. Nature of original as to color and structure.—A dark or colored original will require more exposure than one of normal densities.

If the subject is colored, the emulsion used must be sensitive to that color unless it is required that the color be photographed as black. Glossy surfaces reflect more light than matte or semi-matte surfaces and therefore require less exposure for equal densities.

b. Actinic property of light.—(1) A good actinic light is generally best. Exposures are most accurately determined with the aid of an exposure meter, but experience alone in judging exposure under similar lighting conditions can usually be relied upon with a limited degree of accuracy.

(2) When employing a light of unknown actinic value, it is best to make a test or trial exposure. The proper procedure is as follows: Load the camera in the usual manner. Pull out the dark slide until the entire plate is uncovered and expose for one unit of time, for example, 4 seconds. Push the slide in about 1 inch and expose for the same unit of time. Then successively push in the slide to cover equal steps, exposing each step twice as long as the previous one. The result will be a two-times increase of exposure for each step, the first step receiving 4 seconds exposure, the second step receiving 4 plus 4 seconds, or 8 seconds, and the third step receiving 4 plus 4 plus 8 seconds, or 16 seconds. The fourth step will receive 32 seconds. From the series of exposures thus obtained, an approximately correct exposure can be selected. If a further exposure test is necessary, another test may be made based upon the approximate exposure selected from the above test. This test should be made in much the same manner as the first but at a reduced difference in time. The estimated exposure should be in the middle of the series.

c. Speed and color sensitivity of emulsion.—To produce equal results, a slower emulsion requires more exposure than a faster one. If the original is colored, an increase in exposure is necessary and unless it is desired that the color be photographed as black, it is necessary to employ an emulsion sensitive to that color. Colors photograph as dark or black on a noncolor sensitive material.

d. Amount of reduction or enlargement (bellows extension).—As the subject is enlarged, the required bellows extension becomes longer. The brightness of the image on the ground glass focusing screen varies inversely with the square of the bellows extension; consequently, the *exposure varies directly as the square of the bellows extension.* For example, if two copies were being made, one at the same scale as the original and the other reduced to one-half scale, the exposure of the one-half scale copy is computed as follows: Assume an exposure time of 32 seconds at 1 to 1 scale. The focal length times the scale of the copy, plus 1, is equal to the bellows extension. Assuming a 10-inch lens focused at one-half scale, $10(\frac{1}{2}+1)=15 \therefore 15$ inches is the bellows extension. At a scale 1 to 1, the bellows extension is always two focal lengths, therefore, since light intensity varies inversely as the square of the bellows extension, the following proportion results: Original bellows extension squared is to the new bellows extension squared as the original exposure is to the new exposure, or

$$20^2 : 15^2 :: 32 \text{ second} : x$$

$$\text{Result}=18 \text{ seconds}$$

In a problem of this sort wherein two scales are involved, it is unnecessary when using the same lens to consider the focal length. Prove as follows, assuming identical conditions of above example: Original bellows extension squared is to the new bellows extension squared as 32 seconds is to x. To determine the bellows extension the complete formula would be (focal length $(1+1)^2$: (focal length $(\frac{1}{2}+1)^2$ :: 32 seconds : x. Since the local lengths are identical, it is possible to cancel them in the proportion, so that

$$(1+1)^2 : (\tfrac{1}{2}+1)^2 :: 32 \text{ seconds} : x$$

The result is identical to that of the preceding example, 18 seconds.

e. Speed of the lens.—(1) The speed of the lens is a variable factor, and is governed by the bellows extension in use. The indicated speed on the lens barrel is true only when the lens is focused at infinity. The indicated speed, therefore, is considered only as a guide to the amount of light the lens will transmit in a given length of time. At infinity focus, the projected image is one focal length from the lens. At distances less than infinity, the projected image is at a distance greater than one focal length. Therefore, the light must travel farther from the lens to the focal plane. In copying, the bellows extension is considerably greater than when focused at infinity. In working this problem, it will be found that when copying at a scale of 1 to 1 the working aperture is represented by a number two times the numerical valuation of the indicated *f/* number as engraved on the lens barrel. In making the average copy, the lens speed should therefore be considered as approximately one-fourth its indicated speed.

(2) Copies should be made with the lens at as large an aperture as practicable since the resolving power of a lens is greater at the large stops. A large stop will assist in reproducing the quality of the original. A copy made at a small lens stop tends to show a very evident and undesirable "copied effect."

357. Developing the negative.—The degree of development should be determined from the contrast of the original and the contrast desired in the reproduction. This can best be determined by a study of the subject under good lighting conditions. Unless some means of sensitometric control is available, the time and temperature method of development should be employed. It is very important, therefore, that developers be of standard strength and temperature so as to insure consistent results. This system of development will approach the nearest to sensitometric control without actually using a sensitometer and its applied equipment. Exposing a subject correctly and developing to the full recommended degree of development will cause the copy to have more contrast than the original print. Since it is unusual that an increase in contrast is desirable, a decrease in development is recommended. Therefore, prints made especially for reproduction should be of normal or somewhat less than normal contrast. They should be of a brilliant nature, and if glossy, this brilliance can more readily be retained. However, if the subject is a line drawing or one in which maximum contrast is desirable, the negative should be developed to its maximum or near maximum contrast.

CHAPTER 12

LANTERN SLIDES AND FILM SLIDES

SECTION I

GENERAL

358. Definition.—A lantern slide is a photographic transparency, usually positive, which is adapted for projection in an optical lantern. The general conception of a lantern slide is that it is a glass plate 3¼ by 4 inches with a positive photographic image. Lantern slides may be made on film in various sizes and are then known as "transparencies."

359. Use.—Primarily, lantern slides are used for projection but may be viewed directly by transmitted light. When projected, they are generally used for instruction or the presentation of data to large audiences. To portray a subject better, slides are often made in color which is obtained by a natural photographic color process or is added by tinting or toning.

360. Comparison of slides and prints.—The image of a print on paper is viewed by reflected light and that of lantern slides or transparencies by transmitted light or by means of the projected image. The image density of a lantern slide should be somewhat greater than that of the average print on paper if measured under similar conditions.

361. Care and cleanliness in operations.—Since a slide is designed for projection upon a screen and the image thus magnified many times, the greatest care must be taken at every stage of lantern slide making to preserve the utmost cleanliness, to avoid dust, grit, dirt, or marks of any kind on the slide, as such extraneous particles will be conspicuous in the projection. Therefore, preparatory to beginning work, all trays, containers, and apparatus must be thoroughly cleaned.

SECTION II

GLASS PLATES

362. Sensitized material.—The emulsion used on lantern slide plates is generally bromide or bromo-chloride and is noncolor sensitive. It is similar to a positive film emulsion and is available in several degrees of contrast of which the most common are soft, medium, and hard. As with other positive materials, the more contrasty emulsions are of the slower speeds. Lantern slide emulsions are safely handled in orange-yellow light (series O or OA).

363. Kind of negative required.—Any negative that will yield a good print will also render a good slide. Imperfections, such as scratches, pinholes, or similar defects, are magnified in the projection of the slide upon the screen. Similarly, negatives that have had much hand work done on them, as well as those with harsh contrast, show to great disadvantage in the lantern slide.

364. Printing the slide.—Lantern slides may be printed satisfactorily by either contact or projection. As a lantern slide can be properly placed in a lantern slide projector in a horizontal position only, it is essential that the image be printed on the slide in such a manner that it will be upright when the slide is in a horizontal position.

a. Contact printing.—When lantern slides are printed by contact, the intensity of the printing light should be lower than that for ordinary contact printing since bromide emulsions are faster than ordinary contact emulsions. This may be accomplished by substituting lights of less wattage, by varying the light intensity with a rheostat, or by the use of a diffusing medium such as a white blotter. Mechanical operations of printing are identical with those of ordinary contact printing, but dodging is somewhat difficult because of the small area involved.

b. Projection printing.—Printing lantern slides by projection is more satisfactory than contact printing since dodging is more easily accomplished and the amount of light easily regulated by means of the lens aperture. One of three methods may be employed, as follows:

(1) *Ordinary projection printing.*—Printing may be accomplished with the average type projection printer. If the negative is larger

than the required image size, a special reducing attachment must be used. A reducing attachment is essentially an extended bellows with an auxiliary lens of shorter focal length than that supplied with the projector. The shorter focal length permits greater reductions.

(2) *By means of a camera and negative.*—This system involves the photographing of the negative. Unless the equipment used is especially designed for the purpose, care must be taken that the negative and focal plane of the camera are parallel to each other and that the negative is well within the angle of field. To photograph the negative, it should be mounted in a framework and held flat by placing it between two pieces of clean and flawless glass. The negative should be evenly illuminated from the back with a brilliant actinic light. The negative may then be photographed by use of the transmitted light. Dodging may be accomplished between the light source and the negative, or between the negative and the camera lens. A suitable lens hood should be used to exclude extraneous light. (See fig. 77.)

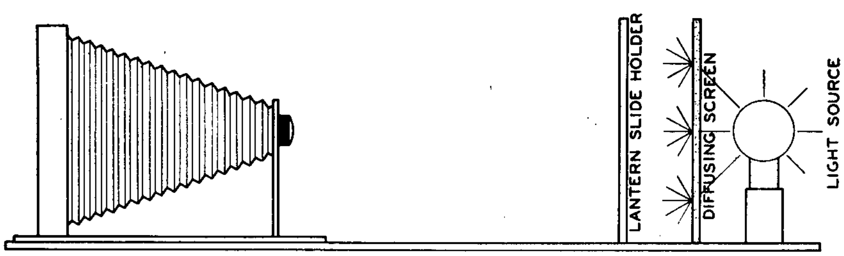


FIGURE 77.—Making lantern slides with a camera.

(3) *By copying.*—When slides are made from prints, a copy negative must first be obtained. This copy may be procured in the usual manner of copying. A lantern slide plate may be used as the negative medium and, if made to the proper size, contact-printed. If a negative print is copied, the result will be a positive without the procedure of printing.

365. Processing the slide.—*a. Developer.*—Lantern slides are developed in developers similar to those required for bromide papers. Because of the wide range of contrast often desired, two formulas are generally recommended by the manufacturer, one producing normal contrast and warm tones and the other producing cold tones of higher contrast. (See app. I.)

b. Development.—A lantern slide plate should be slid into the developer so it will be quickly and evenly covered by the solution. Development should usually be prolonged to the maximum or near maximum allotted latitude of development to insure full contrast, brilliancy of the image, and appreciable highlight density. The progress of development may be observed by examination of the image by transmitted light as apparent from the back of the plate. This examination may be accomplished either by direct light from the safelight or by reflection from a suitable white tray.

c. Fixing and washing the slide.—Slides should be fixed for at least twice the time required to clear and should be washed in running water for a period not less than 20 minutes. They should be carefully sponged prior to drying to prevent the formation of water spots.

366. Finishing the slide.—*a. Masking.*—The usable area of a 3¼- by 4-inch lantern slide plate is approximately 1 inch less than its length and ½ inch less than its width. In the preparation of slides for projection, at least ½ inch on each end and ¼ inch on the long sides should be masked. Any extraneous matter outside the actual picture space should also be masked.

b. Binding.—To protect the emulsion surface from damage, a cover glass is placed over the emulsion side of the plate. It also serves to strengthen the completed slide. Prior to binding, all glass surfaces must be thoroughly cleaned and both cover glass and masked slide must be completely dry. To bind a lantern slide, proceed as follows: Cut a strip of binding tape 15½ inches long; lay face down and moisten the back thoroughly; when limp, turn the gummed side up and moisten this side. Now lay the strip, face up, on blotting paper; place the edge of the slide with its cover glass in position on the strip so that one end of the strip is in the center of a side of the slide and cover glass; then press them down firmly on the strip. Next, turn the slide and cover over on the strip, and over again, and at each movement press the slide and cover while held together firmly on the strip, running the finger along the edge of the binding tape so as to cause it to adhere to the slide and its cover. Next, press the sides of the strips firmly against the glass, pressing down the corner to make a neat joint. Now turn the slide over once more so as to join the ends of the binding strip and make neat joints at the corners by mitering or clipping out the corners of the binding tape, being sure to rub the edge of the binding tape down firmly before pressing the sides of the strips against the glass. A special revolving type of lantern slide vise may be used to hold the slide and cover glass in contact, thus leaving both hands free for the binding.

c. Marking.—A mark, usually a small paper disk, is pasted in the lower left-hand corner of the emulsion side of the finished slide when the image is in an upright position. It is known as the "operator's thumb spot" and is used to facilitate the insertion of the slide in the projector under operating conditions. The rule is to grasp the slide with the thumb of the right hand on the thumb spot. Insert the slide in the lantern-slide carriage from the right-hand side of the projector. The image is then inverted and the emulsion side of the slide is toward the projection lamp.

SECTION III

FILM SLIDES

367. Micro-copies.—A micro-copy is a miniature-sized reproduction. Micro-copies are essentially film slides and are used to project an image in much the same manner as lantern slides. Although they may be made on any small emulsion surface, they are generally photographed on standard-size 16-mm or 35-mm motion-picture positive film. Emulsions of special color sensitivity, speed, and resolving power are manufactured for the purpose.

368. Use.—Film slides are often used for instruction purposes and the presentation of data to audiences. They also have a wide range of uses in photographically recording various records and documents, such as identification work, the collection of important data, the dissemination of information, and the recording of laboratory and research activities. A great many micro-copies can be made on one small roll of film and filed in a small container. This method of filing has decided advantage over the filing of original data, such as newspapers, books, photographs, or lantern slides.

369. Printing.—Micro film slides are not always printed, as the original copy is often used in projection. If they are printed, the best method is to use a motion-picture printer.

370. Developing.—Dodging is practically impossible on such a small area and careful manipulation of exposure and development is therefore essential. Because of the extremely small-scale image, the full efficiency of the lens and emulsion used must be maintained in order to satisfactorily record the image. Therefore, some form of sensitometric control of development must be employed. (See app. I for developers.)

371. Finishing.—Film slides, if projected from a roll, are so made that they are ready for projection. If bound individually, they are generally mounted on cardboard of a size and shape to suit the projector.

372. Masking.—Prints or similar material used in film-slide making should be masked so as to exclude all extraneous material. Any further masking during the process of manufacture is therefore unnecessary. If original negatives are made directly from the subject photographed, as in the case of an outdoor scene, on material similar in size to that of the finished slide, extraneous matter should be excluded from the photograph.

Section IV

COLOR TRANSPARENCIES

373. Definition.—A color transparency is an image made with a natural color emulsion.

374. Use.—Color transparencies are designed to be viewed by transmitted light and are made in various sizes to suit a particular need. The larger sizes are intended for viewing by direct transmitted light and the smaller sizes are intended for projection purposes. If projected, they are mounted on cardboard or glass of a size and shape to suit the projector, but they may be in a roll and projected in a manner suited to roll projection. Color transparencies are often used in the production of separation negatives in color printing processes.

375. Exposure and development.—The development of direct color emulsions is a reversal process which affords a very short latitude of exposure. It is therefore essential that exposures be determined with a high degree of accuracy. Processing should be accomplished with strict adherence to the manufacturer's recommendations.

CHAPTER 13

COLOR PHOTOGRAPHY

SECTION I

GENERAL

376. Definition.—Color photography is true orthochromatic rendition; that is, the reproduction of objects in their natural colors and color brightnesses. Color is the visual interpretation of the various waves of visible light. White light is the simultaneous perception of the visible colors, red, orange, yellow, green, blue, and violet.

377. Types.—Color photographs, as in black and white photography, may be either transparencies or prints. Transparencies are positive photographs on film or glass which are viewed by light passing through the photographs toward the observer, or more suitably, by projection on an appropriate screen and consequent reflection of light in the form of the image. Prints are generally thought of as positive photographs on paper base which must be viewed by reflected light.

SECTION II

METHODS OF REPRODUCTION

378. Additive and subtractive processes.—The two methods of producing color photographs are termed "additive and subtractive." Additive processes are based on the principle of mixing or adding primary color, while subtractive means that certain colors are produced by absorption or subtraction of secondary colors.

a. Additive method.—(1) This method of color synthesis is concerned with the mixing or adding of primary *light* colors. Any two primary colors, when mixed, form a *secondary* color. Blue and red in combination form magenta. Green and red form yellow, and green and blue form blue-green or cyan, as it is commonly called. When the three primary colors are mixed in equal proportion the combination is white. When two primary colors are coupled to form a secondary they are in equal proportion. By varying the proportion of each primary, it is possible to obtain the various shades of the secondary colors. When the additive process is used in color photography, the photograph must be viewed by transmitted light because the process is suitable only for making transparencies. All screen processes employ this principle of color synthesis.

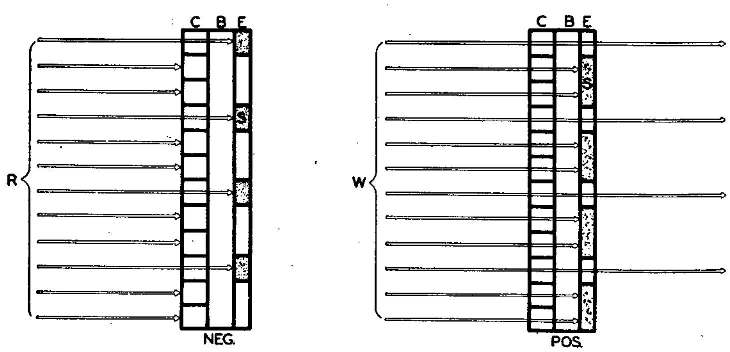


FIGURE 78.—Additive process (mosaic screen).

(2) A commonly used additive method of color reproduction as a transparency is the "screen process." There are many such processes, but the underlying principle is the same in each. A screen process is one in which a colored screen is incorporated with the film and is placed on the side of the film base opposite the emulsion. The exposure is made through the base of the film and consequently must pass through the screen in exposing the emulsion. The screen is composed of filter elements of microscopic size and in the three primary colors, red, green, and blue. These tiny filters separate the colors reflected from a photographic subject into their respective positions in the image. (See fig. 78.)

b. Subtractive method.—(1) *General.*—In subtractive processes, the resultant color is the result of dyed or toned images which are superimposed. Generally, three images dyed or toned in the secondary colors, yellow, blue-green, and magenta, are used (fig. 79). These are also called complementary colors. White light on entering such a combination of images will have certain colors absorbed or subtracted in proportion to the amount of overlap of color within the layers. For instance, if only two layers contained color, such as magenta and blue-green, at a small section of the image and the magenta is not too dense, the green and red will be absorbed or substracted and blue will be the resulting color. A magenta image will subtract green, a blue-green image will subtract red, and a yellow image will subtract blue. The amount of subtraction depends upon the intensity of the color at any one part of the image in that layer.

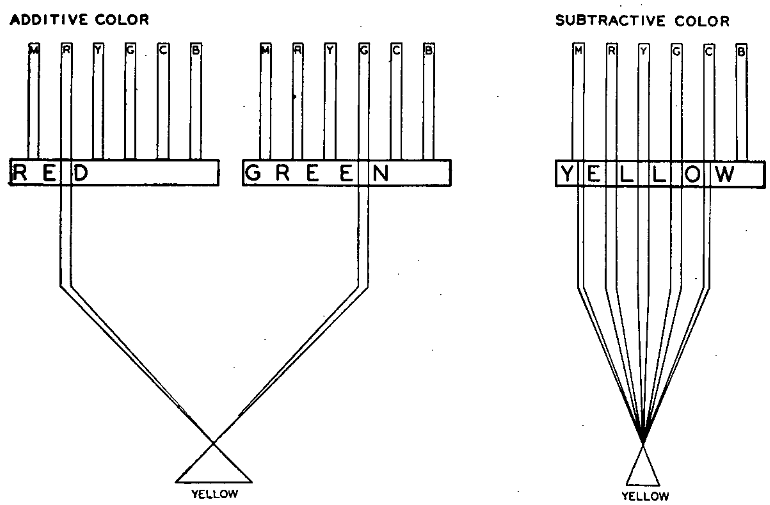


FIGURE 79.—Subtractive process.

This principle of subtraction of color is used in all color printing and also the Kodachrome process of making transparencies.

(2) *The Kodachrome process.*—(*a*) Kodachrome film is composed of three layers of light-sensitive emulsion coated on regular film base which has an antihalation backing. A cross section of Kodachrome

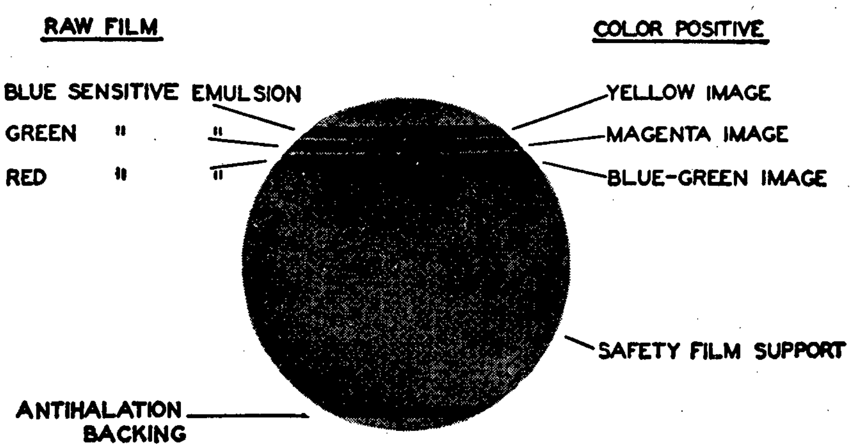


FIGURE 80.—Cross section of Kodachrome film.

film is shown in figure 80. The surface emulsion is sensitive to blue and violet only; the second emulsion is orthochromatic, sensitive to blue, violet and green. A yellow filter dye, incorporated between the first and second emulsion layers, absorbs violet and blue so that the second emulsion responds only to green. The third emulsion is sensitive to red but not to green.

(*b*) This film, after exposure, is first developed as a negative. The three images thus formed are bleached out and the residual silver halide exposed and developed in "coupler" developers. The resulting images are positive and dyed with colors complementary to the colors recorded by the individual emulsion layers. The image in the top layer formed by blue light is transformed into a yellow positive; the image in the center layer formed by green light is transformed into a magenta positive; and the image in the bottom red sensitive layer is transformed to a blue-green positive. Where these dye images overlap each other, they produce, when viewed by transmitted light, different colors depending upon the proportion of color in the overlapping images. Where the images do not overlap but there is dye present in one image, the color of the dye itself is evident. At a point where none of the layers have dye, white light will result; at a point where all three layers have a full quantity of dye, no light is transmitted and black results; and when each layer contains a proportionate amount of dye not in full quantity, neutral gray is evident.

379. Color printing.—*a.* In color printing processes, three negatives are made, each one through a different filter. The filters used are red, green, and blue, the primary colors. These filters have sufficient overlap in transmission so that the entire visible spectrum or color range is covered. From each of these negatives, a separate positive is made. The positive image is formed by exposure through the thin portions of the negative which represent the parts of the subject which were of such a color or colors to cause little or no exposure in the negative. Since these portions of the negative cause the positive exposure, the positive image necessarily cannot be dyed with a color similar to that of the filter through which the negative was made, so they are dyed a color which absorbs the filter color. For example, a negative made through a red filter will appear thin at those parts of the image corresponding to blue and green in the subject. The positive made from this negative must then be colored blue-green which absorbs red. In like manner, the green filter negative will produce a positive which will be colored magenta; and the blue filter negative a positive which will be colored yellow. These colored images are bleached before the dyeing process and no silver remains. The images are on film base and must be transferred in some manner to paper to obtain a single print consisting of three superimposed images which, in conjunction, and correct color proportions, reproduce the subject in natural color. The method of transfer of images varies with the process of printing being used.

b. The three principal color printing processes in present use are the wash-off relief process, the chromatone process, and the carbro process.

(1) *Chromatone* (toning).—Positives are made on special stripping paper from the tricolor negatives. These positive images are toned chemically to produce images of the required colors which are complementary to the colors of the filters through which the negatives were made. These colored positives are stripped from their bases and superimposed on gelatin-coated paper to make the final print, or may be superimposed on a clear base to produce a transparency.

(2) *Wash-off relief* (imbibition).—Positives are made from the separation negatives on special film and an image of tanned or hardened gelatin produced. The exposure of the positive is made through the base of the film leaving the image next to the base. The image is developed and followed by a bleaching bath which hardens the gelatin around the image and leaves the unexposed emulsion unhardened. The silver image is also bleached completely. The unhardened emulsion is then washed off in hot water which dissolves it. The remaining gelatin, which composes a relief image on the base, is next placed in an acid hardening fixing bath. This relief image on film base is called a "matrix." By dyeing one of the relief images with the proper color and placing it in close contact with gelatin coated paper, the dye transfers to the paper. The gelatin on the paper has been chemically treated to "imbibe" the dye, hence the term "imbibition." (See fig. 81.) The next matrix is dyed and superimposed in register over the first transfer. The third matrix is dyed and the colored image transferred in the same manner as the second matrix. The three-colored images in superimposition on paper produce the colored print. With proper handling, the color reproduction can be made quite accurate. This process has an advantage for production work, in that a great many prints can be made from one set of matrices since the final print is a result of dye transfer. As in the chromatone process, the three dyed matrices may be superimposed without dye transfer to make a transparency.

(3) *Carbro* (colored pigment).—This method involves the formation of relief images composed of colored pigment. The pigment is incorporated in gelatin in the manufacture. These pigment images

are superimposed to form the print or transparency, and the entire process must be repeated for each print or transparency. The process is rather long and delicate but gives excellent color rendition.

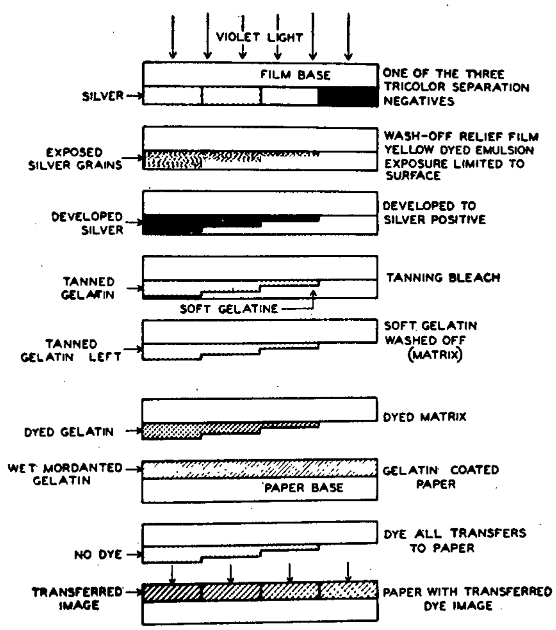


FIGURE 81.—Steps in wash-off relief process.

SECTION III

ILLUMINATION

380. General.—By any process of color photography, correct color reproduction is directly dependent upon the distribution of color emitted from the source of light. Both the screen processes and the Kodachrome process have two specific emulsions, one for artificial light and one for daylight use. Daylight contains a great amount of blue light, whereas artificial light is deficient in blue in comparison.

381. Artificial light.—Emulsions made for use with artificial light are sensitized for use with certain types of tungsten illumination and the use of other than the recommended source will result in improper color balance. The specific type of illumination to be used for a particular emulsion is generally specified. If more than one lamp is used, the others should be of the same type. For instance, Kodachrome type A is corrected for use with photoflood lamps, and any lamps of different color emission would disrupt the color balance of the finished photograph.

382. Daylight.—Emulsions made for use with daylight should be used only with light sources having color emission equal to that of daylight. There are only certain hours of the day when daylight illumination is correct for this film. These hours on the average are from 9:30 AM to about 3:30 PM depending upon the location on the earth's surface, weather, and season. Filters have been devised by the manufacturers whereby photography with color film may be accomplished at any time of day by application of the filter designated to change the color distribution to that recommended for the film. Other filters have been prepared for use with artificial light film in daylight, or daylight film in artificial light, or for using artificial light film with artificial light sources which differ from the recommended source.

SECTION IV

EXPOSURE AND DEVELOPMENT

383. Cameras.—In exposing direct color film, such as that using a screen process or Kodachrome, any camera may be used if it has a color corrected lens with normal aberrations eliminated. The lens must be so corrected that the primary colors (red, green, and blue) will be focused very close to the same plane for accurate results.

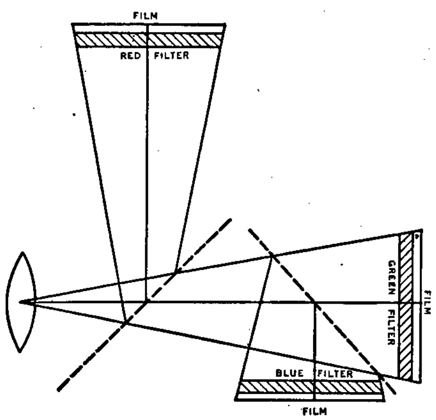
a. When three negatives are made with the appropriate tricolor filters, one of four distinct methods may be employed:

(1) Exposure with a one-shot camera which makes all three pictures at one time through the lens (fig. 82). The films are used in the camera in separate positions and two of the negatives may be made either by reflection of light or by application of a bipack film.

(2) Three separate exposures with each of the tricolor filters. These exposures can be made with an ordinary cut film or plate camera by changing holders and filters for each exposure.

(3) Three separate exposures with a camera having a "repeating back" whereby the film can be changed rapidly for each exposure.

(4) Separation negatives made from direct color film using a contact or projection printer and appropriate tricolor filters. This



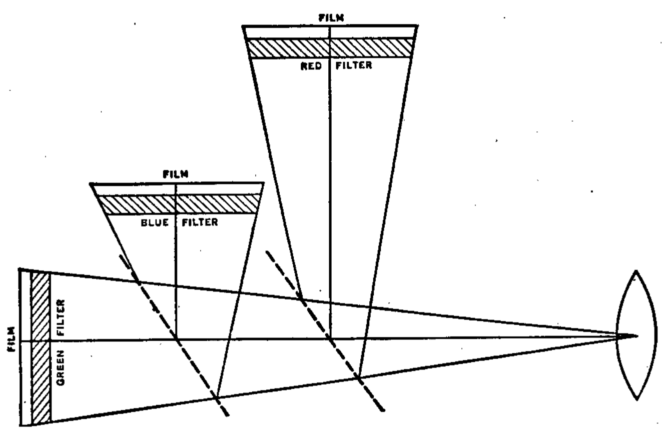


FIGURE 82.—One-shot color cameras.

method is of particular use when prints are required from existing transparencies.

b. Of these four methods of making separation negatives, the first is the most satisfactory. However, special films or plates must be used in one-shot cameras and the cameras are costly. The second method is slower and cannot be used where there is any possibility of movement of the subject during the time necessary to make the exposures. The chief advantage of this method is that it does not require a special camera or special films. The third method is better than the second in that the time necessary to make the three exposures is decreased. The fourth method usually requires the use of a good enlarger and a special set of filters but is quite satisfactory. It has an advantage in that color prints can be produced entirely in the laboratory.

384. Exposure.—*a.* Direct color film has very little exposure latitude. The maximum tolerance for superior photographs in color is one-half a normal *f* stop on either side of the correct exposure. This small variation in exposure latitude necessitates the use of an accurate exposure meter in determining correct exposure. Inspection of image brightness on a ground glass screen is not accurate enough for color photography. Overexposure or underexposure beyond the recommended latitude will result in incorrect color reproduction.

b. In making separation negatives, the filter factors must be taken into accurate consideration. Overexposure or underexposure in one or more of the negatives will result in unbalanced results in the positives and consequent poor color balance in the final transparency or print. For accurate results the factors of the filters to be used should be determined for the film employed in making the negatives and with the light source to be used in the photography.

385. Development.—*a.* In processing photographs made by a screen process, a method called "direct reversal" is used. After exposure, the film is developed in a recommended developer, and a negative image produced. This negative is placed in a bath called a bleach which completely reduces the silver image, changing it to a transparent compound of silver which is not sensitive to light. The film is then exposed to any good light source for a sufficient length of time to obtain complete exposure in the formerly unaffected portions of the emulsion which still contain sensitive silver bromide. The next operation is to develop this exposed emulsion to obtain a positive silver image in "reverse" of the negative image.

b. As in any reversal process, overexposure of the original is ascertained by too thin highlights, while underexposure is evidenced by darkened highlights and dense shadows. Correct exposure is essential in order to obtain the proper proportion of highlight density between positive and negative for accurate results. In competent hands, direct reversal is both simple and rapid. The time needed is somewhat longer than that required for ordinary negative processing, but the finished photograph is a positive ready for use either in projection or by direct observation.

c. Kodachrome film is processed by the manufacturer because of the complications encountered in obtaining the dyed images in the triple layer. This entails a loss of time in obtaining color transparencies by this method.

d. Separation negatives are developed in ordinary developers. They must, however, be developed to the same contrast in order to obtain correct color contrast in relation to the separate colors involved. Too much contrast in a negative will result in an excess of a particular color in the shadows in the print because the shadows will receive too much exposure in the positive. This variation in contrast will be more apparent in the highlights due to the low highlight densities which would be present in a print.

SECTION V

APPLICATION

386. General.—*a.* Since color photography is in a sense still in the initial stages, there are a great many obstacles to be overcome for accurate color reproduction. To produce an accurate print in color requires a great amount of knowledge and skill. The time required to produce such a print is decidedly long by any existing process. For these reasons, color photography at its best is in the production of transparencies.

b. Of the two common methods of making transparencies, the subtractive process is the most suitable. The additive process is not so satisfactory because the amount of light absorbed by the color screens renders the image dark and somewhat dull unless a powerful light source is used. In the additive process which employs screens, a granular effect or pattern is produced due to the composition of the screens. In projection, the definition or sharpness of the image is materially affected by this pattern. It is difficult to make good color prints from additive color transparencies for this same reason.

387. Aerial photography.—Color photography is especially applicable in the interpretation of aerial photographs.

a. The recognition of road conditions is simple in a color photograph, since the actual surface of a road would reflect its own color, thereby making identification of the material easy. Whether the surface was macadam, cement, gravel, dirt, or any other material would be fairly obvious, whereas in black and white photography the distinction of the various shades of gray is depended upon to recognize the material.

b. Depth is more apparent, even in a single photograph, because of the fact that actual color difference between objects is easily distinguishable. This makes the measuring of heights comparatively easy because the color of most objects differs from the shadow so that the actual length of the shadow could be more definitely determined, and from this length and knowledge of the time when the photograph was made plus direction of the airplane's flight, the actual height of the object is a simple computation. In black and white photography, the shadow blends with the object making calculation less accurate.

c. In wartime, the greatest use of color photography is the detection of camouflage as it is difficult to produce artificial color to match the colors in nature. Artificial color records differently from natural color, so that the contrast between the two is obvious. Painted shadow, artificial leaves, or any other contrivance used in producing camouflage is apparent. The depth, newness, or use of trenches are distinguishable in color photographs.

388. Ground photography.—A photograph in color will show things as they occur naturally and not as the photographer can make them by retouching or any other similar device. It will be more pleasing to the eye and more realistic than any black and white photograph.

CHAPTER 14

LABORATORY OPERATIONS

SECTION I

FUNCTIONS WITHIN THE UNIT

389. General.—The efficient operation of a photographic laboratory unit requires a logical grouping of all the functions of the unit into subdivisions (fig. 83) which may be called sections, details, or be otherwise designated; the assignment of suitable personnel to each section; and the operation of each section in coordination with the other sections. A logical subdivision of a photographic unit would be into four sections, as follows:

a. Administrative.
b. Photographic files.
c. Supply, repair, and transport.
d. Photographic production.

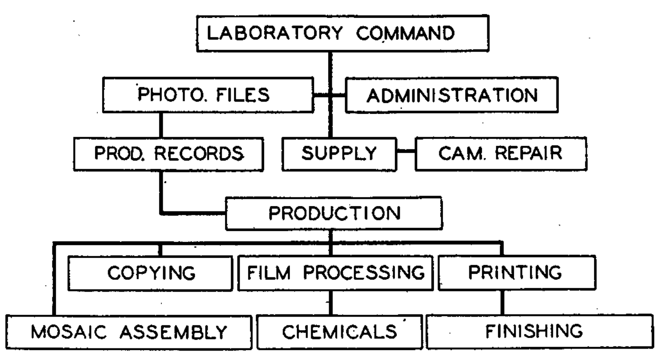


FIGURE 83.—Photographic unit functional chart.

390. Administrative section.—The administrative section is charged with the maintenance of administrative records and the rendition of administrative reports. The discharge of this function is covered in detail in Army Regulations.

391. Photographic files.—The maintenance of negative files, the titling and plotting of negatives, the compilation of records and index maps, and the rendition of reports related to the results of photography are the functions of photographic files.

392. Supply, repair, and transport section.—This section is responsible for requisitioning, housing, and issuing photographic equipment and supplies; rendering reports concerning matériel; maintaining matériel records; repairing and testing cameras; and the tactical control of allotted transportation.

393. Photographic production section.—This section is charged with negative processing, including lantern slides and films; printing, including contact, restitution, transformation, enlargement and reduction; stereograms, reconnaissance strip and mosaic assembly; and mosaic, map, and document reproductions.

SECTION II

MATÉRIEL

394. General.—The principal items of matériel issued to the photographic unit include portable or mobile photographic laboratories, supply trucks and motorcycles; developing, printing, enlarging, restituting, transforming, copying, and other laboratory apparatus; photographic film, plates, paper, chemicals, and many small items of accessory equipment.

395. Laboratories.—*a. Types.*—There are three general types of housing provided for photographic laboratories: permanent laboratory buildings; portable laboratories, or temporary buildings operated with portable equipment; mobile laboratories.

(1) *Permanent.*—Permanent laboratories are used at permanent bases. Buildings of substantial construction are designed and provided for the housing of photographic laboratories at all peacetime air bases. However, the technical equipment for the operation of these laboratories is portable, with the exception of sinks and utilities, and so-called permanent laboratories must be prepared to evacuate and set up operating facilities in another location upon short notice.

(2) *Portable.*—Portable laboratories are used in garrison or in the field. They are capable of being transported readily by normal ground or water facilities, and some types by air.

(*a*) *By air.*—These laboratories are constructed of light-weight tents with especially designed light-weight compact technical equipment. Others are small, cabinet type darkrooms capable of closing into a compact carrying case, and are complete, self-contained units which may be used in aircraft or merely transported thereby.

(*b*) *Other than by air.*—Laboratories portable by air may be moved by normal ground and water transportation facilities. However, larger tents than those designed for air transportation may be used with the standard technical equipment. The use of standard technical equipment with improvisation of local existing construction into darkrooms and workrooms is considered a very practical form of a portable laboratory.

(3) *Mobile.*—Mobile laboratories are used in garrison or in the field. A laboratory structure capable of mobility on land, water, or in the air, is termed a mobile laboratory. It may be capable of limited photographic production while enroute, or of full capacity operation within a short time after establishing a new base. The lack of an adequate water supply reduces the quantity of production below that of the rated technical capacity of the unit.

b. Flexibility.—Portable and mobile laboratories may have darkrooms designed for developing and printing in a single unit, or separate units may be required for different types of darkroom work. Portable and mobile laboratories permit flexibility in the size of the photographic organization inasmuch as additional units may be assigned or attached to the original laboratory. However, because of the compact arrangement of the darkrooms of a portable or a mobile laboratory, it is always advisable to utilize additional working space. This space may be secured by using paulins adjacent to the portable and mobile laboratories, by tentage, by existing buildings, or by temporary construction to provide protection against wind and weather. The amount of space needed depends upon the size of the photographic organization and the type of work being performed; that is, a unit engaged in mosaic assembly needs more illuminated workroom space than one whose mission requires only the delivery of unmounted prints.

c. Preparation for movement.—Commanders of portable and mobile laboratories must be familiar with the shipping dimensions of their equipment and its total weight. In case of water shipment, it is essential that the commander know whether the maximum linear and cubic dimensions permit shipment below deck in the average transport, or whether it must be carried as a deck load. Units will be trained to prepare rapidly for movement and also to go rapidly into photographic production upon reaching a destination.

d. Lighting and power systems.—Electricity for lighting and power in temporary or mobile laboratories should be procured from existing lines to as great an extent as possible. When outside current is not available, the portable generating system provided for field use must be employed.

e. Water systems.—All mobile laboratories are equipped with water pumps. Flexible hose is provided for connection of the pumps with a nearby water pipe, well, stream, or other water source. Each unit also is equipped with a water tank which supplies the faucets. Collapsible water tanks are carried for use in tents and temporary laboratories.

396. Procurement of equipment and supplies.—Current supply regulations prescribe the manner of obtaining equipment and supplies. Matériel is obtained by requisition or by local purchase.

397. Loan of equipment.—The loan of Government property for private use is prohibited. The equipment issued a photographic unit is to enable it and related flying units to discharge their functions. As the proper use of this equipment is only in the performance of such functions, the personnel assigned to discharge them should be the only persons allowed to use such equipment.

398. Records.—Current regulations prescribe the matériel reports that should be made and records to be retained in the photographic unit. Regulations advocate the use of a bin card or form of perpetual inventory for expendable photographic supplies. This should balance at all times, but irrespective of the present or any future system of account for supplies, the laboratory commander must always be able to determine instantly the quantity of supplies on hand and must know the extent to which the laboratory can operate. Air Corps Circular No. 15-81 prescribes the manner of obtaining expendable supplies from local agencies. The maintenance of consumption records within darkroom subdivisions is impracticable.

SECTION III

OPERATION

399. Authority for photographic work or projects.—The laboratory will engage in those phases of photography as directed by the tactical commander. The allotment of photographic materials to a photographic unit is in an amount sufficient for the training requirements of the unit and of the Air Corps organization to which the unit is attached or with which it is associated. Extensive photographic projects, therefore, which require the use of material in quantities greater than the amount allotted for training purposes, will be undertaken only when directed by higher authority.

400. Training.—*a.* By far the most important work done by the photographic unit during peacetime is training in the practice of photography. Work should be so performed that personnel will obtain individual experience of a kind that will prove valuable during military operations, and as far as the quantity of the particular work will extend, exercise in the teamwork that is so necessary during war. Individual technical efficiency should be developed to a high degree, but unit efficiency is paramount. Therefore, the training of the unit must be balanced in all sections and in the various types of missions which the unit may be expected to perform.

b. Practice will improve the quality of the product and the teamwork efficiency of the unit. The laboratory commander should endeavor to maintain an even flow of the various types of missions into the unit in order to maintain unit and individual proficiency with equipment and technique. Army Regulations and technical instructions contain standing orders for many types of photographic missions. These may be supplemented by the laboratory commander whenever required for individual or unit training.

401. Distribution of products.—Photographs will be distributed in accordance with the order authorizing their production.

a. Photography in connection with public relations is subject to the provisions of AR 600-700 and special instructions published from time to time.

b. Regulations classifying and governing restricted photographs are contained in AR 350-5. The unit commander will individually supervise whenever prints or other products are made from negatives of secret or confidential nature. Only the required number will be produced, and the prints or other products will be properly safeguarded during finishing. Negatives and all prints therefrom will be disposed of immediately, in accordance with orders of competent authority.

c. Air Corps Circular No. 95-4 requires that examples of photography be submitted semiannually to the matériel division.

d. The Chief of the Air Corps requires photographs of general service and public interest to be submitted monthly.

e. Official photographs made in a photo unit by military personnel using Government matériel and supplies are property of the United States. The selling of such photographs, negatives, or any photographic products therefrom, or their distribution in *any manner* except through regular channels, is prohibited. This prohibition extends to photographs of any kind which photographic personnel have been directed to make for training purposes.

f. All photographs distributed by the Air Corps will be marked or stamped on the back: "Official Photograph—Published only with the permission of the Chief of the Air Corps." All copyright privileges concerning any official photograph are expressly reserved by the War Department. No person will be authorized to copyright any official photograph.

g. Photographs released for publication by proper authority will contain a credit line to read as follows: "Official Photograph, U. S. Army Air Corps."

h. In preparing photographic prints, enlargements, negatives, lantern slides, and any other photographic products for shipment by mail, express, or otherwise, care must be taken that proper provisions are made for their protection against damage in transit. Ordinarily, prints, negatives, and lantern slides should be packed in reinforced pasteboard box containers wrapped with paper. Large prints should be packed flat between heavy cardboard when practicable. When such prints are shipped in mailing tubes, they should be rolled with the image side out. This will prevent excessive curling when the photographs are removed from the container. Each package of photographs should have on the outside the address of the consignor. Each package or roll of photographs mailed under penalty label should contain a copy of either the original order, a letter of transmittal, or a reference thereto.

402. System of handling.—*a.* The routine procedure in handling work must be systematic. The sequence of operations required in production should be performed as efficiently and economically as in any properly managed shop, and the laboratory commander should always be on the alert to improve the system or technique whenever it is apparent a reduction in labor or materials will result.

b. The workrooms must be logically and conveniently located with reference to one another, and within them the apparatus must be properly placed. Failure to observe these elementary principles governing proper organization and arrangement of facilities causes a great loss of efficiency, apparent from the confusion resulting from the movements in the same place of a number of men, each with different tasks, and from the unnecessary walking around necessitated by the inconvenient location of workrooms and apparatus. In making arrangements that will eliminate such unsatisfactory conditions, the requirements of quantity production should be visualized, and the ideal physical plant should locate workrooms, apparatus, and men in a manner that will produce a steady flow of work that can be accomplished with minimum time and effort. In order to do the work required during military operations, the movements of a man in performing a single work operation must be studied with the view of changing or eliminating some of them in order to economize his time and energy. The production of a photograph should be organized along the principle of "line production" in which each workman performs the minimum variety of operations, but the maximum number, in order that the output attain the peak in quantity and quality.

403. Standard methods.—Laboratory maintenance processes and methods must be standardized to prevent confusion, to economize time and material, and to maintain or improve quality of workmanship. Laboratory rules and regulations should be published covering cleanliness and orderliness, section or room arrangement, use of water and lights, breakage and replacement, labeling of chemicals and sensitized material, handling of chemical solutions and partly used boxes of papers and films, handling of negatives, general care of equipment, and establishing definite laboratory inspection periods.

404. Allocation of personnel.—*a.* Personnel duty assignments to definite rooms or sections within the laboratory build morale. A chart bearing names of personnel and illustrating relationship of their work to that of the laboratory as a whole assists in creating teamwork, tends to maintain efficiency during frequent periods of personnel exchange and substitution, reduces friction, and establishes responsibility.

b. Personnel assignments should result in a proper distribution of the functions of the sections among the personnel, both with regard to individual special qualifications and relative numerical requirements, based on amount of personnel assigned or available to the laboratory. Maximum teamwork can be obtained only when each subdivision has assigned to it men with special aptitudes in quantity to handle exactly the amount of work required of that section, and is provided with an even flow of work involving all the phases of photography for which that section of the laboratory is designated and equipped.

c. The laboratory chief, file clerk, chief film processor, chief printer, and supply clerk should have the status of noncommissioned officers. Administrative duties can be dispatched by a junior clerk under proper supervision.

d. The laboratory chief will normally be the senior enlisted man present. He will assist in general supervision of the plant, matériel, production, and personnel, and enforce the routine procedure and system prescribed by the laboratory commander. He should anticipate supply and personnel requirements, and in general, facilitate teamwork and undelayed production. He should emphasize and augment section responsibility to the end that the loss of personnel within sections shall not be unduly felt in the laboratory as a whole. Individual work assignments should be avoided in favor of section assignments. Production requirements should be clearly understood by all personnel in a section, though responsibility in the section is vested in the senior section man.

405. Photographic files.—*a. General.*—The photographic files section and its subdivision, production records, is the connecting link between sectional functions in the laboratory subdivisions. Photographic files and records function more smoothly and are better maintained if kept separate from unit administration, even though small or newly formed laboratories utilize the same personnel for the two sections. The field desk accommodations allotted unit administration are insufficient to contain the specialized and comprehensive records common to photographic production. Also, it is not customary or desirable to move photographic files and related production records with the unit for either temporary or permanent change of station, provided that photographic facilities will remain in some form to serve local requirements. It is usually inimical to production to place administrative personnel in supervision of files and production records, and this material impedes the prompt discharge of administrative function incidental to change of bases.

b. Types.—Laboratory units administer two types of photographic negative files and records.

(1) *General.*—The general or miscellaneous files contain both ground and aerial negatives and the correspondence relating to them. These files accumulate incidental to routine production orders which the usual quantity of training supplies builds up, and they do not require a redistribution of personnel or an increase of working hours as they will engage personnel for only brief intermittent periods.

(*a*) *Work orders.*—To facilitate general or miscellaneous production, a suitable work order blank form should be adopted by the laboratory. The following entries will be made on this form: Date initiated, serial number of work order, consignee, production specifications, negative file numbers, production accomplished, cost statement (if required), distribution authentication, and monthly production entry.

(*b*) *Monthly production record.*—A blank form adapted to the entry of individual work order numbers, subject reference, and monthly recapitulation of work order production figures should be adopted and used. Completed work orders may be filed after entry on the monthly production record, which may be filed after assisting in the rendition of the Training and Operations Report required by Air Corps Circular No. 15–10.

(2) *Projects.*—Size and requirement of cost reimbursement determine whether an approved photographic request is termed a project. Some Air Corps photographic missions are extensive and require project handling, but usually projects are cooperative work with other branches of the War Department or Federal agencies. It is important to recognize a project as such in its initial stages and organize for it during the period when adequate flight and plot maps, matériel specifications, and priorities are being formulated or received and estimates are compiled. These requirements overburden a normal photographic files section and it is under these circumstances that the normally atrophied production records section is

reinforced substantially. This can best be accomplished with additional personnel in the files section at the expense of darkrooms or other sections. These men should undertake the more mechanical work of titling films and compiling index maps under the close direction of the files clerk who should individually prepare project folders for the inclusion of the project basic authority, all specifications, original plot maps, correspondence, letters of transmittal and acknowledgment, completed project work orders, and production costs. A project folder is prepared for each project in the laboratory and totals of production records therein are transferred to the monthly production record for inclusion in the Training and Operations Report.

Because of the continuity of work and similarity of specifications, project production is relatively simple in the darkrooms, but because of volume, irregularity in negative titling, and unusual correspondence requirements, the files section is best served by a sharply delineated production records section which is handled by the chief file clerk. This section assumes the proportions necessary to the project; that is, supervising files and obtaining special titling and storage, maintaining priorities as established by the tactical commander, and limiting miscellaneous work during the period. It is charged with ascertaining and maintaining specifications; estimating time, cost, and special supply requirements; progressive cost compilation; supervision of negative titling; plotting and index map reproduction; project work order initiation; verification of products; distribution authentication; correspondence; project report preparation and the possession by the unit of a complete file of records at completion of the project. Although the production records section is always active, its duties are normally so slight that its function is not emphasized in the files section. At the close of a project, production records assumes this position, at which time the minor records incidental to general or miscellaneous production are resumed by the files section.

(*a*) *Project work order.*—Project production can be greatly facilitated by the use of a special work order blank form. Frequently, when the size of the project justifies, the blank form may include those specifications not subject to change. As a rule, processing instructions are consistent on all related orders and can therefore be brief, though exact, with reference to papers and amounts. Unusual and adequate space should be allotted that part of the form listing the file numbers of negatives covering the flight lines which are the subject of the camera exposure record. The form should accommodate flight line reference and establish the roll and negative numbers pertaining thereto. The form should include date initiated, roll number, project name and number, specifications, negative file numbers by strips, production accomplished, cost statement (if not otherwise provided for), distribution authentication, and monthly production entry. The completed project work order should be filed with the project records.

(*b*) *Cost estimates, records, and reports.*—The laboratory is customarily required to estimate project costs, under function subdivisions, prior to approval of the project and its final specifications; cost estimates are required in every case involving cost reimbursement prior to engaging the project. Specifications must be closely observed and considered with regard to plant, equipment, personnel, supplies, and priorities before statements regarding cooperative projects are submitted. Frequently the project, as specified, is impracticable with the equipment possessed, will prevent all other training gained from miscellaneous photography, and will require the use of supplies not standard in the Air Corps. Specifications unsuited to equipment should be taken exception to and the cooperative agency must be required to furnish direct to laboratory stocks not standard. Wastes in connection with projects through the employment of inexpert personnel are properly chargeable to training, but cognizance of these discards must be taken in estimates, and where special papers and supplies are furnished by the cooperative agency, must be borne by the cooperative agency. In the photography of forested and unmapped areas where much plotting is verified by print assembly not otherwise required, as much as 25 percent of the printing costs are production waste insofar as delivery is concerned. Special laboratory cost recapitulation blank forms may be originated, if desired, but the practice is generally discouraged because suitable work order forms make it unnecessary from the viewpoint of the laboratory. The expenses of flight personnel and equipment are, within specifications and regulations, chargeable to the project cost but their maintenance and compilation are the responsibility of flight personnel. Projects involving cost reimbursement usually require cost reports at the end of the fiscal year and a complete report on the project is required at the completion of the project. This report is made by the tactical commander and requires the rendition of reports to him from all units involved. Chemical costs are the most difficult to ascertain since project work is accomplished in conjunction with other work, and it is impracticable to distinguish between the two in darkroom procedure. It is most practical to ascertain the number of prints or the number of negatives that may be processed in a given amount of chemical solution, then ascertain the unit cost of the various solutions and compute for total production. The use of a cost form such as shown below, will assist the preparation of original cost estimates, emphasize the items which are properly the subject of cost record maintenance, and materially contribute to the formation of final cost reports.

PROJECT COST CARD

Project name and number-------------------- Completion date ------------

SPECIFICATIONS: Include altitude flown, scale of negatives, map scale furnished, camera type, overlap each way, area by name, number of prints, size and type, to whom delivered, etc.

Exposures made -------- Negatives used -------- Prints forwarded -------

Flying time ---- hrs. ---- mins. Prints forwarded by size -------- --------

Area by square miles ---------- Prints forwarded by size -------- -------

Cost per square mile $---------- Prints forwarded by size -------- --------

		A. C.	Dept.	Total
Aircraft costs:				
Oil (qts.PH)----for----(hrs.)(total)----@----¢		$-----	$-----	
Gas (gal.PH)----for----(hrs.)(total)----@----¢		$-----	$-----	
Grease (kind)------------(amt.)-------@----¢		$-----	$-----	
	Total cost	$-----	$-----	$-------
Miscellaneous costs:				
Telegrams------------------------	Total cost	$-----	$-----	
Hangar rentals--------------------	Total cost	$-----	$-----	
Parcel post-----------------------	Total cost	$-----	$-----	
Bills of lading--------------------	Total cost	$-----	$-----	
Local repairs, facilities, incidentals--	Total cost	$-----	$-----	$-------
Film costs:		A. C.	Dept.	
------rls 9½″ by 75′ @ $-------		$-----	$-----	
------rls 6″ by 120′ @ $-------		$-----	$-----	
------rls 7″ by 12′ 3″ @ $-------		$-----	$-----	
------shts 8″ by 10″ @-------¢		$-----	$-----	
------shts 20″ by 24″ @$-------		$-----	$-----	
	Total costs	$-----	$-----	$-------

A. C. Dept.	Paper costs		
-----	----- gr (type)-----(size)------@ $-----	$-----	$-----
-----	----- gr (type)-----(size)------@ $-----	$-----	$-----
-----	----- gr (type)-----(size)------@ $-----	$-----	$-----
-----	----- gr (type)-----(size)------@ $-----	$-----	$-----
-----	----- gr (type)-----(size)------@ $-----	$-----	$-----
-----	----- gr (type)-----(size)------@ $-----	$-----	$-----
-----	----- gr (type)-----(size)------@ $-----	$-----	$-----
-----	----- gr (type)-----(size)------@ $-----	$-----	$-----

Chemical costs	Air Corps	
------ tanks (3 gal.) developer (film) @---------	$-----	$-----
------ tanks (— gal.) developer (film) @--------	$-----	$-----
------ tanks (20 gal.) developer (film) @--------	$-----	$-----
------ tanks (25 gal.) developer (film) @--------	$-----	$-----
------ gallons developer (film) @--------------	$-----	$-----
------ gallons developer (film) @--------------	$-----	$-----
------ gallons developer (paper) see note @------	$-----	$-----
------ tanks (3 gal.) fixing bath (film) @--------	$-----	$-----
------ tanks (—gal.) fixing bath (film) @--------	$-----	$-----
------ tanks (20 gal.) fixing bath (film) @-------	$-----	$-----
------ tanks (25 gal.) fixing bath (film) @-------	$-----	$-----
------ gallons fixing bath (film) @--------------	$-----	$-----
------ gallons fixing bath (paper) see note @-----	$-----	$-----
Total cost	$-----	$-------
Total project cost		$-------
Reimbursement to Air Corps		$-------

Chemical figure basis:
Per qt. developer: 60 8 x 10; 15 16 x 20; 10 20 x 24.
Per gal. fixing bath: 50 8 x 10; 12 16 x 20; 8 20 x 24.

c. Duties and responsibilities.—(1) All production and training should be covered by work orders initiated by files. Work required by custom or competent authority to be undertaken instantly must be reported promptly to the files section for initiation of laboratory work order. Verbal requirements will always be followed by initiation of laboratory work orders, which should be accomplished by the closely supervised files section rather than by an individual. An entry of each work order initiated will be maintained in the files section on the monthly production record, and after accompanying the material through the various sections, production entries will be made after completion and the order filed under monthly records.

(2) The files section is charged with titling and the storage of recorded and titled negatives. Untitled negatives do not form a part of negative files and retention of such material should not be

required. Files must accomplish the plotting of negatives and initiate the reproduction of index maps to accompany photographic products. Immediate steps must be taken to obtain and insert in negative roll cans index map reproductions of suitable scale which will identify the negatives. Every can must contain an index map.

(3) Files are charged with ascertaining knowledge of and furnishing information relative to the status of uncompleted work. Decisions involving priorities are coordinated and executed through the files section which must know the obligations of the laboratory and the state of current production. The laboratory commander and laboratory chief must support the supervision contemplated above or the system will be impaired to the extent that satisfactory production will be accomplished only when the material is personally conducted by them through the laboratory. This cannot be the case because the commander has administrative duties and his chief laboratory technician must devote much of his time to darkroom production quality, teamwork, plant maintenance, repair, and personnel and operating problems.

(4) The files section should verify the quantity and quality of production preliminary to distribution.

(5) Files must effect or authenticate distribution.

(6) Air Corps Circular No. 95-3 governs the titling and identification legend to be used on all negatives. A loose-leaf file book should be maintained for negative files, listing each negative, adequately supported by subject cross-reference index cards. Photographic units are authorized an Air Corps 14-inch typewriter for photographic files and production records and reports.

(7) Flight and laboratory personnel must cooperate in the composition of a complete cameraman's exposure log which supplies all the information required by the tactical commander, processing sections, and titling requisites of photographic files. This log must be delivered to the laboratory with exposed films.

(8) Film identification is the responsibility of the camera operator and must be satisfactorily accomplished prior to film delivery. Tolerance of other identification means will result in the dumping of partially unidentified films into the files section, the initiation of unspecific work orders, and the partial identification with the aid of verbal description. In this case, identification has been made by the files section and it is the repository of remaining untitled negatives incapable of being filed and about which there is hesitation to

discard. The laboratory commander should avoid the acceptance of unidentified films unless untitled production is required in emergency.

(9) Photographic files are further charged with the compilation and maintenance of all records and correspondence relating to photography and the preparation of reports thereon. Competent assistance may be required.

406. Handling films and negatives.—*a.* Proper and methodical arrangements for the accommodation of films and negatives must be made from the time of arrival of exposed films in laboratory to final disposition of negatives. This is essential to prompt and orderly production and the reduction of fire hazards.

b. Films should arrive in processing sections accompanied with work orders containing instructions relative to processing and priority. Information on the work order must include date and hour of exposure, subject or type of mission or both, altitude and weather conditions, filter, shutter speed, aperture, camera and magazine numbers, and exact number of exposures. The film following the last exposure should, in the case of roll film, be marked with the work order number assigned and after processing be respooled and delivered in the can with the work order bearing appropriate production entry to photographic files section. Cut films usually are in small quantities and are identifiable with the subjects of the camera operator's log. After processing, they should be placed in preservers in the order of subject listing and delivered with the work order to files section. In the files section, the negatives remain in a receptacle labeled "awaiting titling." After preparation for further production, which may involve discard of negatives and part rolls, they are placed in a receptacle marked "awaiting production," the work order now containing negative numbers and further processing instructions and the whole material so located in the receptacle that priority of further processing is indicated. It should be customary for the chief printer to visit this section hourly and scan the orders taking the first for production as printing progress permits or when priority demands. Printing orders customarily are delivered to the finishing section after darkroom work is completed, and in the cases of small orders on cut films, the films remain with the work orders and are delivered with prints to files. Roll films must always be returned direct to the files section and placed in the receptacle marked "completion." All other negatives, their prints and the work orders are delivered to this receptacle by the printing chief who supervises the finishing section.

c. Unless essential, the partition of rolls should be avoided. Roll use is the safest and most expeditious manner of handling negatives from exposure to final storage discard. Rolls must always be kept in cans when not the subject of immediate use.

d. Field operations involving the handling and processing of films may differ materially from the normally accepted methods. Those work orders whose first requirement is speed in delivery usually involve only small parts of rolls or single exposures. Several exposures may be developed in about 3 minutes, rolls and part rolls in about 5 to 6 minutes. After the emulsion has cleared in fixation bath, single exposures and strips of about three exposures may be placed, base down, upon ferrotype plates and the surface water on the emulsion swabbed by damp chamois or squeegeed off with print squeegee or other flexible rubber wiper without practical injury to the negatives. Soaking for 2 minutes in an ethyl alcohol bath, followed by airing in heated or dry room or facility for 1 or 2 minutes, produces negatives sufficiently dry for printing. Methyl alcohol should not be used because it will attack a film support. It may be necessary to refix and wash these negatives later, though usually this is impracticable. Negatives apart from full rolls may be given normal handling in chemical baths and then be cut, washed, and dried individually or in short strips, with the dispatch indicated, and commensurate with the ability of other sections to handle further production of the order. Night processing for morning delivery is customary and drying in portable facilities involves the intelligent use of any heated or otherwise desirable facility. Frequently films may be strung across the ceilings or nearby structures, however poorly adapted to use, and drying hastened by the use of alcohol, gasoline, or kerosene stoves or pots from a safe distance below. A full use of cook tents has been made in the past where prior hot fires have produced a pocket of warm, dry, upper air. Any expedient capable of hastening the drying of films in poor accommodations must be utilized to the extent consistent with common sense safety factors.

e. Acetate base films are brittle when dry and in dry climates or well-heated interiors they shatter or break readily. When allowed to peel from the roll as a ribbon of considerable length, tearing invariably occurs. These negatives are required to be wound on spools, emulsion out, and it is important that the first spooling be accomplished in this manner since much of the excess drying occurs immediately after processing and the shape assumed by the negative base at that time will persist throughout the life of the negative. Original excess drying can be avoided on forced air dryers, but when recourse is had to free air afforded by slotted wheels or makeshifts, the negatives should not be left overnight and must be spooled immediately after they are sufficiently dry to prevent adhesion.

f. Film discards and scraps constitute a fire hazard, a subject treated in AR 850-65. Strict adherence to smoking prohibitions and the designation of one closed waste receptacle for all film discards will reduce film fire hazards.

g. AR 850-65 and Technical Order No. 10-5-1 prescribe proper storage facilities and precautions.

h. Negative files accumulate quickly and untitled negatives in storage are not tolerated. Laboratory commanders should insist that the requirements of film identification be met. Initiative must be exercised in the transfer or destruction of negatives of questionable value to the unit by representations made to the tactical commander and, when necessary, through him to interested agencies.

407. Locations of laboratory sections.—Essential teamwork within the laboratory depends largely upon plant lay-out. Even in the more or less complete mobile units where section location is predetermined, there is a tendency to develop auxiliary accommodations which are frequently essential to required production. This addition, the construction or enlargement of portable laboratories and the utilization of permanent laboratories, should be such as to facilitate the exchange of information and materials in the course of production.

a. Administration and supply are closely correlated in the photographic unit. In small units and particularly in the field where intense personnel utilization is necessary to production requirements and plant restrictions, they are advantageously housed together while their joint location within the laboratory is relatively unimportant.

b. Print finishing is usually final production. Where possible, it should be accomplished under controlled atmospheric conditions and adequate illumination. Whatever the plant accommodations, vigorous action should be taken to create a housed weather and wind protected finishing section, as wind, dust, and dirt defeat print finishing quality and the orderly assembly of print orders. All printing darkrooms are best located within a single block, the center of which is occupied by the finishing section and the print passage which is facilitated by the use of wall light traps rather than doors equipped with light traps or curtains that delay or hamper ready tray passage.

c. Photographic files should be located directly opposite or contiguous to the finishing section. Files must know currently the progress of orders through the printing and finishing sections and every effort should be made to facilitate this intercourse. Field operation requires the closest contact between these sections and limited housing frequently results in dual use of existing facilities.

d. The creation of an adequate negative processing section in a portable laboratory is the first consideration of the laboratory personnel. The negative processing section requires no special location within the unit, though proximity to the files section is advantageous to both.

408. Chemical mixing section.—*a.* Chemical solutions should be prepared in a well-ventilated room unrelated to the storage or processing of sensitized materials. A weighing table, equipped with suitable scales, should adjoin a sink of generous dimension for the actual mixing. A series of formula cards should be employed in card index form and the formulas, while conforming to the proportions furnished in appendix I, should be computed in the largest amount of solutions consistent with the needs of the laboratory in order to minimize human error in weighing under adverse conditions. The cards should be dated and initialed by the individual responsible for the quality of chemical solutions within the laboratory in all cases where the specifications differ from the basic formula in any respect, including simple increase or decrease in volume. The use of special and nonstandard solutions create confusion and lack of confidence and responsibility in the laboratory and do not contribute to quality work. The feasibility of the use of only one formula in varying strengths for all standard processing of sensitized materials has been well established. This practice should be quickly adopted in time of emergency or for field operation.

b. The film processing section has the prime need of faultless chemical solutions; therefore, chemical mixing is treated as a subdivision of that section and selected men should be rotated to relieve tedium under the supervision of the individual responsible for film processing.

409. Ventilation.—Adequate ventilation of laboratories is necessary for the comfort and health of the workmen. A good ventilating system is installed in the mobile laboratories and proper ventilation must always be provided in other laboratories. When it becomes necessary to use a poorly ventilated space, the men should be divided into reliefs and observe a schedule which will allow frequent respites and access to the fresh air outside. Care must be taken in building light traps that a sufficiently free passage is left for air.

410. Camera repair.—*a.* The supply section is charged with the custody, maintenance, and repair of cameras in small laboratories and during field operations of all photographic laboratories. Extensive laboratories and those housed in permanent buildings usually facilitate equipment repair by the creation of a camera section having only nominal connection with the supply section. It is treated as a part of production and possesses equipment in the same sense that darkrooms are equipped for operation. Such a camera section is charged with custody, issue, maintenance, and repair of all cameras, and such camera mission preparation as is desirable. It may be required to accomplish the repair of all cameras and such camera mission preparation as is desirable. It may be required to accomplish the repair and servicing of all equipment within the limitations imposed by Technical Orders covering equipment.

b. Routine maintenance of equipment is best accomplished by the adoption and use of equipment cards which provide information required to institute unsatisfactory reports and condense instructions for maintenance or servicing required by Technical Orders. This, or a similar card, should be maintained for individual items of equipment employing gearing or electric motors, such as print wringers and contact printers and other major items having working parts subject to replacement. The cards should be assembled according to the inspection period to which assigned; for example, all printers may be designated for service on the 5th and 20th day of each month, print washers and wringers on the 6th and 21st. The back of the card should be ruled off to form columns under date for the initials of the workman performing the required inspection, oil, greasing, service, and overhaul.

PHOTOGRAPHIC EQUIPMENT MAINTENANCE RECORD

Name________________________________ Type__________ Technical Order______
Date received____________ Purchase order No______ Located_________________
Contractor______________________________________ Contractor's model No______
Electric motor numbers___________________ and________________ H. P________
Periodic service required____
____
____
____
Oiling instructions____
____
Greasing instructions____
____
Inspection period to which assigned____
Was unit received new____________ in good condition___________________________
Date installed________________ Is machine being used__________________________
Remarks ____
____
____
____
____
____

(If parts have been removed from this machine, their disposition and necessity for such action must be shown under "Remarks")

SEE BACK OF CARD FOR RECORD OF SERVICE.

c. Only such repairs or adjustments of cameras or laboratory apparatus will be made in the photographic unit as in the judgment of the unit commander can be undertaken with safety or without damage to the equipment. Extensive repair to cameras and laboratory equipment will not be attempted in the photographic unit. Cameras and equipment will be returned to the base supply.

d. Air Corps Circular No. 15-45 requires the maintenance of a Camera Inspection Record for each aircraft camera.

411. Alterations of equipment.—Equipment will be altered only when so ordered by higher authority. Such changes are usually directed by Technical Orders or Technical Radiograms. Equipment will be repaired as indicated in the appropriate Technical Order.

412. Storage of chemicals.—Photographic chemicals are stored in accordance with Technical Order No. 24-1-1.

413. Experiment within the laboratory.—Prolonged test and experiment is not the function of a service unit and is detrimental to the efficiency of the laboratory. Only those relatively simple and brief tests will be made that are necessary to the rendition of intelligent and comprehensive unsatisfactory reports.

414. Service test equipment.—New types of equipment are usually given thorough tests by field units before general adoption and distribution in the Air Corps. Sometimes photographic units will be called upon to make practical tests of the new types of photographic equipment. Before undertaking such tests, thorough instruction should be received in the use of the equipment, the tests should be full, fair, and impartial as possible, and the recommendations made should be consistent with the best interests of the military service.

415. Care of equipment.—The production of satisfactory work by a photographic unit is to a large extent dependent upon the working conditions of its equipment. Frequent tests and inspections should be made of equipment by the unit commander for the purpose of ascertaining its operating efficiency, and particularly whether the detailed instructions that should have been previously issued by him governing its use are being strictly observed by the personnel of the unit. Prompt and appropriate disciplinary action should be taken in any case of neglect or abuse of equipment or disregard of orders or instructions concerning it. Any inherent defects in equipment because of poor design or defect in manufacture should be made the subject of an unsatisfactory report.

416. Water and electricity.—Modern photography is completely dependent on water and electricity.

a. Base field laboratories require adequate quantities of water under pressure. Any water system serving human needs and consumption may be presumed to be satisfactory for photographic purposes, though frequent filtering will be necessary. It is preferable to maintain a laboratory only where adequate water is available rather than undertake the correction of a deficiency. Mobile and advanced laboratories are equipped to function from local water systems, from streams or ponds nearby, or by the use of auxiliary mobile water tanks. These laboratories can operate successfully on most clear waters and roily waters are relatively satisfactory after filtering. Waters with sufficient chemical taint to preclude ready use should be avoided by advanced field laboratories.

b. Base field laboratories are always located where adequate outside electric current is available. Foresight must be exercised in estimating current requirements, and line capacity to the various laboratory sections must be given fullest consideration to prevent line overload during periods where considerable electric equipment is in simultaneous operation. Mobile laboratories are equipped with power source and wiring closely calculated for estimated requirements. Additional light and power outlets, often desirable under exigencies, should be made only after line capacity and power source have been augmented or determined to be sufficient for the contemplated extension. Every effort should be made to obtain electric supply from outside source in every circumstance, since it is more dependable and less limited.

417. Storage of inflammable liquids.—Inflammable liquids in use in the laboratory should be held to absolute minimum at all times and storage facilities for partly used or unsealed containers should be maintained at a distance from the laboratory. Technical Order No. 10-5-1 refers to such storage.

418. Laboratory fire exits, darkroom exit signs, and electric fixtures and restrictions.—AR 850-65 covers the marking of exits and exit sign specifications and prescribes electric circuits and fixtures used in connection with certain phases of film processing.

419. Fire extinguishers.—*a. Soda and acid.*—(1) Soda and acid fire extinguishers contain chemicals for generating carbon dioxide rapidly, as by mixing sulfuric acid with a solution of sodium bicarbonate when the apparatus is inverted. Water is the extinguishing agent. The pressure exerted by gas forces a stream of water on the fire. This appliance is effective on incipient fires in ordinary burning materials such as wood, paper, textiles, rubbish, or a combination of these materials where the quenching and cooling effect of quantities of water is of the first importance.

(2) To operate, turn upside down. Direct the stream at the base of the flames. Follow the flames with the stream.

Caution: Do not use on electricity, gasoline, or any other liquid that is lighter than water.

b. Foam.—(1) The basis of the foam system of fire extinguishing is the use of chemicals that combine to create a large volume of carbon dioxide gas confined in tough, durable bubbles of foam easily applied and readily adhering to any burning surface. The mixture spreads out as a blanket, smothering the fire. It is most effective on oil fires. In ordinary burning materials, the foam may be used to coat the surface of the burning area, as a blanket. It does not penetrate so well as water.

(2) To operate, turn upside down. The stream should be directed against the inside of the opposite wall of the tank above the burning liquid so as not to splash fire. Walk around the fire if possible. If the fire is on the floor, stand back and allow the foam to fall on the fire without much force, preventing the spread of flames.

Caution: Do not use on electricity.

c. Carbon tetrachloride.—(1) When a stream of this liquid is directed against a burning surface, the heat causes it to evaporate instantly, forming a heavy gas that displaces the air in contact with the burning material. It is a nonconductor of electricity and may be used on all types of material fires except photographic films and similar plastics. Rooms, closets, or confined spaces should be ventilated immediately after using the extinguisher.

(2) To operate, turn black wheel on the back of the extinguisher. Direct the stream at the base of the flames and work around the fire rapidly. If the fire is in a container or tank, direct the stream against the inside opposite wall above the level of the burning liquid.

Caution: Do not use on photographic films as the toxic phosgene is liberated.

d. Carbon dioxide.—(1) This extinguisher may be used for films, alcohol, gasoline, oil, paint, varnish, paraffin, lacquer, inflammable chemicals and liquids.

(2) To operate, pull lock pin on the top of the extinguisher then turn the valve on top of the extinguisher as indicated by the arrow on top of the valve. This will discharge the gas in the extinguisher. Direct the discharge as close to the fire as possible, applying first to the edge and at the bottom of the fire, and progressing forward and upward. Move the discharge horn slowly from side to side. Continue the discharge even after the fire has been extinguished to cool the liquid and prevent possible reflash.

Caution: Do not turn on extinguisher until in position ready to fight the fire.

Appendix I

FORMULARY

1. General.—It is quite possible to select one developing formula which will give satisfactory results with many sensitized materials, but certain emulsions definitely require specific formulas to insure optimum results. If a developer is being selected for a particular use, both the sensitized material and the specific type of work to be accomplished should be carefully considered. The recommended procedure in processing is to use the developer which is specified for the particular emulsion. The purpose of this formulary is to furnish the data necessary for mixing and using solutions as to chemicals, quantities, temperature, method of use, dilution, and length of time a material is to be treated.

2. Time of development.—The developing time as stated in the directions with each developed formula is not intended to be definite for all materials and types of work, but is merely an approximate guide to be used when the correct time is not known. It is impossible to state one developing time for all materials because the photographic image is influenced by many other factors, such as range of brightness in the subject, type of lighting, inherent contrast of material, emulsion speed, and color sensitivity.

3. Developer formulas.—*a. For negative materials.*—(1) *Normal contrast developers.*

(*a*) *Air Corps specification developer.*

Stock solution

Water (at 100° F.)	96 ounces
Metol	198 grains
Sodium sulfite (des.)	6 ounces, 176 grains
Hydroquinone	1 ounce, 44 grains
Sodium carbonate (des.)	7 ounces, 264 grains
Water to make	1 gallon

Dissolve about one-tenth of sulfite, then the remaining chemicals in the order given. For films in tray, use one part of stock solution to four parts of water. Develop 4 to 6 minutes at 65° F. For tank development, dilute one to four. Develop 5½ to 7½ minutes with continuous agitation.

(*b*) *ABC pyro developer.*

Solution A

Water (at 100° F.)	1 gallon
Potassium metabisulfite	4 ounces
Metol	4 ounces
Pyro (crystals)	4 ounces
Potassium bromide	220 grains

Dissolve about one-half the metabisulfite and then the metol. Dissolve the remainder of the metabisulfite, then the pyro, and last the bromide.

Solution B

Water (at 100° F.)	1 gallon
Sodium sulfite (des.)	14 ounces

Solution C

Water (at 120° F.)	1 gallon
Sodium carbonate	10 ounces

For use, dissolve one part of each solution in six parts of water. Develop 6 to 9 minutes in tray at 65° F.

(*c*) *Metol-hydroquinone-borax developer* (for maximum shadow detail).

Water (about 125° F.)	96 ounces
Metol	106 grains
Sodium sulfite (des.)	13 ounces, 110 grains
Hydroquinone	290 grains
Borax, granular	116 grains
Water to make	1 gallon

Dissolve chemicals in the order given. Use without dilution. Average development time about 20 minutes in tank at 65° F. or about 12 to 15 minutes in tray.

(*d*) *Metol-hydroquinone developer* (for all types of films).

Stock solution

Water (about 125° F.)	64 ounces
Metol	180 grains
Sodium sulfite (des.)	6 ounces
Hydroquinone	1 ounce, 260 grains
Sodium carbonate (des.)	9 ounces
Potassium bromide	108 grains
Water to make	1 gallon

Dilute one part stock solution to 4 parts water. Develop films 4 to 6 minutes at 65° F. in tray.

(*e*) *Metol-hydroquinone developer* (for all cut films and plates).

Stock solution

Water (about 125° F.)	64 ounces
Metol	180 grains
Sodium sulfite (des.)	12 ounces
Sodium bisulfite	120 grains
Hydroquinone	340 grains
Sodium carbonate (des.)	1 ounce, 220 grains
Potassium bromide	96 grains
Cold water to make	1 gallon

Dissolve chemicals in the order given. For tray development, take one part stock solution to one part water. Develop about 7 minutes at 65° F. For tank development, take one part stock solution to three parts water. Develop about 14 minutes at 65° F.

(2) *Process work; high contrast developers.*

(*a*) *Process developer.*

Water (about 125° F.)	64 ounces
Metol	60 grains
Sodium sulfide (des.)	10 ounces
Hydroquinone	1 ounce, 80 grains
Sodium carbonate (des.)	3 ounces, 145 grains
Potassium bromide	290 grains
Cold water to make	1 gallon

Dissolve chemicals in the order given. Use without dilution. Average development time about 5 minutes in tank or 4 minutes in tray at 65° F., or about 4 minutes in tank or 3 minutes in tray at 70° F. When less contrast is desired, the developer should be diluted with an equal volume of water.

(b) *For extreme contrast films* (Gamma range=7 to 10).

Water (at 125° F.)	64 ounces
Sodium sulfite (des.)	4 ounces
Trioxymethylene (paraformaldehyde)	1 ounce
Potassium metabisulfite	150 grains
Boric acid crystals	1 ounce
Hydroquinone	3 ounces
Potassium bromide	90 grains
Water to make	1 gallon

This developer should stand for at least 2 hours before use and should not be used with ordinary process emulsions. Develop about 2 minutes at a temperature of 65° to 70° F. At any higher temperature, the solution rapidly loses its strength. This solution loses strength rapidly in open trays.

(c) *Specification developer.*—This developer may be used also with process film *at full strength*. Develop 4 minutes at 65° F. in tray.

(3) *Fine grain developer* (sodium metaborate).

Water (about 125° F.)	96 ounces
Metol	290 grains
Sodium sulfite (des.)	13 ounces, 110 grains
Sodium metaborate .$4H_2O$ (Kodalk)	116 grains
Sodium sulfocyanate[1] (thiocyanate)	58 grains
Potassium bromide	29 grains
Cold water to make	1 gallon

[1] An equal quantity of potassium sulfocyanate may be substituted.

Dissolve chemicals in the order given. Use without dilution. Average development time about 20 minutes in tank at 65° F., or about 16 minutes in tray.

(4) *Tropical developer.*

Water (at 125° F.)	96 ounces
Para-aminophenol hydrochloride	400 grains
Sodium sulfite (des.)	6 ounces, 290 grains
Sodium carbonate (des.)	6 ounces, 290 grains
Water to make	1 gallon

Dissolve chemicals in the order given, using full strength. Average time of development 7 to 9 minutes in tray at 65° F., and 3 to 4 minutes at 80° F. If the temperature of the developer is 80° F. or above, add 6 ounces sodium sulfate (desiccated) to 1 gallon of solution.

(5) *Speed processing* (for negatives).

Water (cool, 60° F. to 70° F.)	90 ounces
Metol	1¾ ounces, 30 grains
Sodium sulfite (anhydrous)	10 ounces
Hydroquinone	3½ ounces, 60 grains
Sodium hydroxide	3½ ounces, 60 grains
Water to concentration	(about 112 ounces)

Dissolve chemicals in the order given, using full strength. Develop 10 seconds in tray at 80° F. Rinse for the same time.

(6) *Aerial film developers.*—(*a*) *Specification developer.*—Dilute one part stock solution with four parts water. Develop 8 to 15 minutes at 65° F. Automatic tank development.

(*b*) *For tray or tank use.*

Water (at 120° F.)	64 ounces
Metol	128 grains
Sodium sulfite (des.)	9 ounces, 265 grains
Hydroquinone	1 ounce, 75 grains
Sodium carbonate (des.)	6 ounces, 180 grains
Potassium bromide	240 grains
Water to make	1 gallon

Dissolve chemicals in the order given, using full strength. Develop about 15 minutes at 65° F. in automatic developing tank.

b. For positive materials.—(1) *Specification developer.*—Dilute one part stock solution with two parts of water.

Chloride paper	1 to 1¼ minutes at 65° F.
Bromide paper	2 to 2½ minutes at 65° F.
Bromochloride paper	2 to 2½ minutes at 65° F.
Lantern slides	2 to 3 minutes at 65° F.

(2) *For bromide and bromochloride papers.*

Water (at 120° F.)	64 ounces
Metol	88 grains
Sodium sulfite (des.)	3 ounces
Hydroquinone	360 grains
Sodium carbonate (des.)	2 ounces
Potassium bromide	88 grains
Water to make	1 gallon

Dissolve chemicals in order given. Dilute 1 to 1. Develop 2 to 3 minutes at 65° F.

(3) *Chloride paper developer* (for blue-black tones).

Stock solution

Water (at 120° F.)		64 ounces
Metol		160 grains
Sodium sulfite (des.)	5 ounces,	145 grains
Hydroquinone	1 ounce,	190 grains
Sodium carbonate (des.)		10 ounces
Potassium bromide		48 grains
Water to make		1 gallon

Dissolve chemicals in order given. Dilute stock solution in two parts of water. Develop 1 minute at 65° F. or 45 seconds at 70° F.

(4) *Lantern slide developer* (for warm black tones).

Stock solution A

Water (at 125° F.)	64 ounces
Sodium sulfite (des.)	360 grains
Hydroquinone	400 grains
Potassium bromide	200 grains
Citric acid	40 grains
Cold water to make	1 gallon

Stock solution B

Cold water	1 gallon
Sodium carbonate (des.)	4 ounces
Sodium hydroxide	240 grains

Dissolve chemicals in the order given. For use, take equal parts of *A* and *B*. For still warmer tones, take one part of *A* to two parts of *B*. Stir thoroughly before use. Develop about 5 minutes at 70° F.

(5) *Lantern slide developer* (for cold black tones).—Use specification developer, 1 to 2, for 2 to 3 minutes.

4. Fixing solutions.—*a. Acid hardening fixing bath* (for films, plates, papers).

Solution A

Sodium thiosulfate (hypo)	2 pounds
Water to make	1 gallon

Dissolve completely. If hydrometer issued, reading should be 68 at 65° F.

Solution B (hardening bath)

Water (at 125° F.)	56 ounces
Sodium sulfite (des.)	8 ounces
Acetic acid (28 percent)	24 fluid ounces
Potassium alum	8 ounces
Water to make	1 gallon

Dissolve chemicals in the order given. For use, add one part hardener to six parts plain hypo solution. Fix films, plates, or papers for 15 minutes at 70° F.

b. Boric acid hardening fixing bath (more stable and better hardening).

Water (at 125° F.)	80 ounces
Sodium thiosulfate (hypo)	2 pounds
Sodium sulfite (des.)	2 ounces
Acetic acid (28 percent)	6 ounces
Boric acid (crystals)	1 ounce
Potassium alum	2 ounces
Water to make	1 gallon

Dissolve chemicals in the order given. Films and plates will fix completely in 10 minutes in fresh bath.

c. Formalin fixing hardening bath.

Sodium thiosulfate	36 ounces
Sodium sulfite (des.)	7 ounces, 80 grains
Formalin (40 percent formaldehyde)	17 ounces
Water to make	1 gallon

Dissolve chemicals in order given.

d. Nonhardening fixing bath (for paper prints).

Water (at 125° F.)	64 ounces
Sodium thiosulfate (hypo)	2 pounds
Sodium sulfite (des.)	1 ounce, 140 grains
Sodium bisulfite	3 ounces, 140 grains
Water to make	1 gallon

Dissolve chemicals in order given. Do not use above 65° F. Dry prints slowly.

5. Rinse and stop baths.—(*a.*) *Acetic acid rinse* (for papers).

Water	1 gallon
Acetic acid (28 percent)	6 ounces

Rinse prints at least 5 seconds, 65° F.

b. Acetic acid rinse (for films and plates).

Water	1 gallon
Acetic acid (28 percent)	16 ounces

Rinse negative about 5 seconds, 65° F.

c. Tropical hardener rinse (films and plates).

Water	1 gallon
Potassium chrome alum	4 ounces
Sodium sulfate (des.)	8 ounces

To be used after brief water rinse if temperature is below 85° F. If above 85° F., omit water rinse. Discard bath when it appears yellow-green.

6. Reducing solutions.—*a. Subtractive reducer.*

Solution A

Water	16 ounces
Potassimum ferricyanide	1¼ ounces

Solution B

Water	1 gallon
Sodium thiosulfate (hypo)	2 pounds

Add one part *A* to four parts *B*; then add water to make 32 parts. Pour solution over negative to be treated. Examine negative frequently during reduction and remove to wash when sufficiently reduced.

b. Proportional reducer.

Stock solution A

Water	32 ounces
Potassium permanganate	4 grains
Sulfuric acid (10 percent)	½ ounce

Stock solution B

Water	96 ounces
Ammonium persulfate	3 ounces

Take one part solution *A* to three parts solution *B*. When the negative is sufficiently reduced, clear in 1 percent sodium bisulfite. Wash negative thoroughly before drying.

c. Superproportional reducer.

Stock solution

Water	1 gallon
Ammonium persulfate	8 ounces
Sulfuric acid, concentrated	3 drams

Dilute one part stock in two parts water. When reducing is complete, immerse negative in acid fixing bath for a few minutes and wash thoroughly. If reduction is too rapid, dilute further.

7. Intensification.—*a. Mercuric chloride intensifier.*

Bleacher

Water (cool, 60° F. to 70° F.)	28 ounces
Potassium bromide	¼ ounce, 55 grains
Mercuric chloride	¼ ounce, 55 grains
Water to make	32 ounces

After negative is bleached, wash thoroughly and blacken in either of the three solutions given below. These solutions give greater density in the order given.

Solution No. 1

10 percent solution of sodium sulfite. The B solution of ABC developer works satisfactorily.

Solution No. 2

One-half tray strength metol hydroquinone developer (specification developer).

Solution No. 3

10 percent solution of ammonia.

b. Chromium intensifier (for professional films and plates).

Stock solution

Water	32 ounces
Potassium bichromate	3 ounces
Hydrochloric acid (C. P.)	2 fluid ounces

For use, take one part stock to 10 parts water. Harden negative with alkaline solution of formalin before intensification to prevent reticulation. Bleach negative thoroughly and wash for 5 minutes. Redevelop fully in a non-staining developer. (Avoid developers with high sulfite content.)

8. Toning (Sepia toning, redeveloping process).

Bleacher

Water (cool, 60° F. to 70° F.)	18 ounces
Potassium ferricyanide	1 ounce
Potassium bromide	1 ounce
Water to make	24 ounces

For use, dilute one part of above stock solution to one part water.

NOTE.—While the above solution may be mixed in the order given, the operation is facilitated by grinding ferricyanide and bromide together, with mortar and pestle, and dissolving in the water.

Redeveloper

Water (at 100° F.)	12 ounces
Sodium sulfide (not sulfite)	1 ounce

For use, one part stock solution to eight parts water.

NOTE.—Use enamel trays (no metal exposed) for the above two solutions. If blue (or greenish) spots appear on prints it is an indication of iron in water, either from trays or in the ferricyanide itself.

Caution: As the fumes of sodium sulfide are harmful to sensitized emulsions, this chemical should not be mixed or used in a place where the fumes will come into contact with such materials.

9. Miscellaneous formulas.—*a. Tray cleaner.*

Potassium dichromate (or bichromate)	16 ounces
Water (cool, 60° F. to 70° F.) to make	112 ounces
Sulfuric acid (C. P.)	16 ounces

Dissolve potassium dichromate and then add sulfuric acid slowly to the solution. Adding the acid too fast will result in overheating.

Caution: Never add water to acid, but add acid to water.

b. Tray cleaner (nitric acid).—For cleaning Allegheny metal trays, buckets, and other containers, use a 25 percent solution of nitric acid.

c. Ferrotype polish.

Benzol (benzole or benzene)	15 ounces
Paraffin shavings	75 grains

The above amount of paraffin is correct for black ferrotype tins. For chromium ferrotype tins, use 25 to 50 grains of paraffin to 15 ounces of the solvent.

d. Print bleacher (for converting prints into line drawings).

Water (cool)	12 ounces
Potassium iodide	65 grains
Iodine (black crystals)	10 grains
Water to make	16 ounces

Bleach print until image has disappeared, then fix in *plain fixing bath.*

e. Gum arabic (adhesive).

Water	1¾ gallons
Salicylic acid	160 grains
Gum arabic	8 pounds
Glycerin	16 ounces

NOTE.—If this solution is inclined to ferment with age, the amount of salicylic acid may be increased.

f. Hypo test solution.

Water (cool, 60° F. to 70° F., preferably distilled)	8 ounces
Potassium permanganate	4 grains
Sodium hydroxide	8 grains

Use ¼ dram (15 drops) of above solution to 8 ounces of water, preferably distilled. Pour ½ ounce of this solution in small graduate. Take equivalent of six 4- by 6-inch prints from water, drain hurriedly, and allow drippings to drip into the ½ ounce of solution for 30 seconds. The least trace of hypo in the water draining from the prints will cause this violet solution to turn to an orange color. If more hypo is present in the drippings, the solution will change to a greenish-yellow color. As certain impurities in water will cause similar discoloration of the solution, a number of drops of tap water, equivalent to number of drops to be dropped from prints, should be dropped into the ½ ounce of violet-colored solution. If no change in color takes place, any change in color that will take place from the water drained from prints will be due to the presence of hypo which will prove that the prints have not been sufficiently washed.

g. Hypo eliminator.

Water	16 ounces
Hydrogen peroxide (3 percent)	4 fluid ounces
Ammonia (3 percent)	3¼ fluid ounces
Water to make	32 ounces

Directions for use: Wash prints for 30 minutes at 65° F. Immerse each print for 6 minutes in hypo eliminator solution, then wash for 10 minutes and dry. Capacity of bath is about fifty 8 x 10 prints or the equivalent per gallon.

Appendix II

LIST OF CHEMICALS

Name and chemical formula	Ounces of chemical in 100 ounces (fluid) of saturated solution at 40° F.	70° F.	Uses in photography
Acid, acetic $HC_2H_3O_2$	[1] M. A. P.	[1] M. A. P.	Acid rinse baths, fixing baths. (Poisonous.)
Acid, citric $H_3C_6H_5O_3$	78	88	Keeper in developers, clearing baths.
Acid, hydrochloric or muriatic. HCl	M. A. P.	M. A. P.	Platinotype and carbon processes and intensification with mercury.
Acid, nitric HNO_3	M. A. P.	M. A. P.	Making emulsions, keeper in pyro developer. To clean stainless steel trays.
Acid, oxalic $H_2C_2.O_42H_2O$	7¼	14½	Keeper in developers. Used in preparing potassium and ferrous oxalate. (Poisonous.)
Acid, salicylic $C_6H_4(OH)$ COOH	¼ approx.	¼ approx.	Preservative in glues, mucilages, and gum arabic mucilage.
Acid, sulfuric H_2SO_4	M. A. P.	M. A. P.	Fixing baths, bleachers, rinse baths, tray cleaners.
Acetone C_3H_6O	M. A. P.	M. A. P.	Solvent of celluloid, used in varnishes and film cement.
Alcohol, ethyl C_2H_5OH	M. A. P.	M. A. P.	Used in stock solutions of M. Q. developer to prevent crystallization. Rapid drying and cleaning.
Alum, potassium $Al_2K_2(SO_4)_324H_2O$	6¼	11½	To harden gelatin in hardening baths and fixing baths. To purify water.
Alum, potassium chrome $K_2Cr_2(SO_4)_324H_2O$	15½	20½	Used in fixing baths and hardening baths for negatives.
Amidol (diaminophenol Hydrochloride). $C_6H_3(OH)(NH_4)_2HCl$ (1,2,4)	20½	26	A developing agent especially suited for tropical developers.
Ammonia NH_4OH	M.A.P.	M.A.P.	To ripen emulsions, accelerator in pyro developers, as a cleaning agent.

[1] Mixes all proportions.

LIST OF CHEMICALS—Continued

Name and chemical formula	Ounces of chemical in 100 ounces (fluid) of saturated solution at		Uses in photography
	40° F.	70° F.	
Ammonium bromide NH_4Br	52	57	Making emulsions. Restrainer in developers.
Ammonium chloride NH_4Cl	26	30	Making emulsions. Rapid fixing agent in fixing baths.
Ammonium persulfate $(NH_4)_2S_2O_8$	52	62	Used in negative reducers.
Ammonium thiocyanate NH_4CNS	62	73	Used in toning. Can be used as a silver solvent in fixing baths.
Amyl acetate $C_5H_{11}C_2H_3O_2$	Soluble in alcohol or ether		Preparation of varnishes.
Barium sulfate $BaSO_4$	Insoluble	Insoluble	Also called blanc fixé. Used in making baryta paper.
Borax (sodium tetraborate). $Na_2B_4O_7.10H_2O$	2½	7¼	Used in toning, in developers. Acts as a restrainer with pyro and as an accelerator with hydrochinone.
Calcium chloride $CaCl_2$	Very soluble	Very soluble	Packed in containers of emulsions to absorb moisture.
Carbitol acetate (Diethylene glycol) (monoethyl ether acetate).	M. A. P.	M. A. P.	Used as a substitute for glycerin to soften emulsions prior to ferrotyping.
Caustic potash (See potassium hydroxide). KOH	78	83	Accelerator in process developers. In hypo test solutions.
Caustic soda (See sodium hydroxide). NaOH	50	83	Accelerator in process developers.
Diaminophenol hydrochloride(See Amidol). $C_6H_3(OH)(NH_4)_2.HCl$ (1, 2, 4)	20½	26	Developing agent. Often used in tropical developers.
Formalin (formaldehyde) CH_2O	M. A. P.	M. A. P.	40 percent formaldehyde. Used to harden gelatin in fixing baths and hardening baths. Used to prevent germicidal growths in trays, tanks, etc.
Glycerin $C_3H_5(OH)_3$	M. A. P.	M. A. P.	Used as a solvent for some chemicals. Used to prevent curl of films and papers.

LIST OF CHEMICALS—Continued

Name and chemical formula	Ounces of chemical in 100 ounces (fluid) of saturated solution at 40° F.	70° F.	Uses in photography
Glycin (Paroxyphenylglycin). $C_6H_4(OH)(NH.CH_2COOH)$	Soluble in alkaline solution		Nonstaining developing agent. Trade name: Athenon.
Gold chloride $AuCl_3$	79	100+	Toning of P. O. P. and in hypo-alum-gold toning processes.
Hydroquinone $C_6H_4(OH)_2(1, 4)$	4¼	6¾	Developing agent. Generally used in combination with metol.
Hypo (See sodium thiosulfate). $Na_2S_2O_3.5H_2O$	73	93	Most common fixing agent. Used in fixing baths. Farmer's reducer and in bleaching processes.
Iodine I_2	Practically insoluble		In bleachers for prints.
Iron (Ammono-citrate of) $Fe_2(NH_4)_2(C_6H_5O_7)_3$	----------	----------	Making blueprint paper and iron toning processes.
Lead nitrate $Pb\ (NO_3)_2$	39½	51	In intensification and in solutions for combined toning and fixing.
Mercuric chloride $HgCl_2$	4	6¼	Very poisonous. Used in intensification.
Mercuric iodide HgI_2	Insoluble	Insoluble	Very poisonous. Soluble in solution of sodium sulfite, hypo or potassium iodide. Intensification.
Metol (monomethyl paraminophenol sulfate). $C_6H_4(OH)(NH)CH_3H_2SO$	5¼	8¼	The most used developing agent. Trade names: Elon, Rhodol, and Pictol.
Para-aminophenol hydrochloride. $C_6H_4(OH)(NH_2).½(COOH)\ (1, 4)$	1¼	2½	Developing agent, especially suitable for tropical developers. Trade name: Kodelon.
Paraformaldehyde, or trioxmethylene. $(COOI_2)_3$	----------	----------	Accelerator used in process developers where extreme contrast is desired.

LIST OF CHEMICALS—Continued

Name and chemical formula	Ounces of chemical in 100 ounces (fluid) of saturated solution at 40° F.	70° F.	Uses in photography
Paraphenylene diamine $C_6H_4(NH_2)_2$	---------	-------	A skin irritant. Used as a fine-grain developing agent.
Potassium bichromate $K_2Cr_2O_7$	6¾	14½	Photo-mechanical and pigment processes, print bleachers, intensification, tray cleaners.
Potassium bromide KBr	50	56	Making emulsions. The most used restrainer. Print bleachers.
Potassium carbonate anhydrous. K_2CO_3	83	85	Accelerator in developers. Rapid drying of negatives.
Potassium cyanide KCN	46	52	Deadly poison. Used in bleachers and intensification processes. Can be used as a fixing agent for some emulsions.
Potassium ferricyanide $K_3Fe(CN)_6$	30	36	Used in bleachers and reducers.
Potassium hydroxide (caustic potash) KOH	78	83	Accelerator in process developers. Hypo test solutions.
Potassium iodide KI	99	104	Manufacture of emulsions, restrainer in developers, intensification, bleaching solutions.
Potassium metabisulfite. $K_2S_2O_5$	47	57	Keeper or preservative in developers. In fixing baths as an acid and preservative.
Potassium oxalate $K_2C_2O_4.H_2O$	29	36½	Used as a developer in the platinotype process.
Potassium permanganate. $KMnO_4$	3¼	6¾	Reducers, stain removers, tray cleaners, hypo test solutions, bleach bath in reversal process.
Pyrogallic acid (pyro) $C_6H_3(OH)_3(1, 2, 3)$	36	57	Staining developing agent. Used only in developers for negatives.

LIST OF CHEMICALS—Continued

Name and chemical formula	Ounces of chemical in 100 ounces (fluid) of saturated solution at		Uses in photography
	40° F.	70° F.	
Silver bromide $AgBr$	Insoluble	Insoluble	Making emulsions.
Silver chloride $AgCl$	do	do	do
Silver nitrate $AgNO_3$	109	135	Making emulsions, intensifiers, physical developers.
Sodium bisulfite $NaHSO_3$	52	52	Preservative or keeper in developers. Acid and keeper in fixing baths.
Sodium bromide $NaBr$	67	73	Making emulsions. Restrainer in developer.
Sodium carbonate (anhydrous). Na_2CO_3	10¼	24	The most used accelerator in developers.
Sodium carbonate (monohydrated). $Na_2CO_3.H_2O$	12	28	The most used accelerator in developers.
Sodium chloride (common table salt). $NaCl$	31	31	Making emulsions. Restrainer in developers. Hypo-alum toning bath.
Sodium hydroxide (caustic soda). $NaOH$	50	83	Accelerator in process developers.
Sodium metaborate, crystal.	23	33	Accelerator in fine-grain and other negative developer. Trade name: Kodalk.
Sodium sulfate (anhydrous). Na_2SO_4	5¼	20½	In preparation of barium solfate. In negative developers to prevent excessive swelling emulsion. Tends to coagulate gelatin.
Sodium sulfate, (crystal). $Na_2SO_4.10H_2O$	10¼	41	Same uses as sodium sulfate, anhydrous.
Sodium sulfide (fused) NaS	13½	17¾	Redeveloper in sepia toning. Blackener in process work.
Sodium sulfide (crystal). $Na_2S.9H_2O$	36¼	47	Same uses as sodium sulfide, fused.

LIST OF CHEMICALS—Continued

Name and chemical formula	Ounces of chemical in 100 ounces (fluid) of saturated solution at		Uses in photography
	40° F.	70° F.	
Sodium sulfite (anhydrous.) Na_2SO_3	17½	28	The most used preservative in developers and fixing baths. Blackener in intensification.
Sodium tetraborate (see borax). $Na_2B_4O_7.10H_2O$	2½	7¼	Used in toning processes. In developers acts as a restrainer with pyro and as an accelerator with hydroquinone.
Sodium thiosulfate crystal (hypo). $Na_2S_2O_3.5H_2O$	73	93	Most used fixing agent for silver halides. Used in fixing baths and in Farmer's reducer.

APPENDIX III

TABLES USED IN PHOTOGRAPHY

WEIGHTS AND MEASURES

Weights

Pound (lb.)	Ounces (oz.)	Grains (gr.)	Grams (gm.)
1	16	7, 000	453. 60
	1	437. 5	28. 35
		1	. 065
			1

Liquid measure

Gallon (gal.)	Quarts (qts.)	Ounces (oz.)	Drams (dr.)	Minims (min.)	Cubic centimeters (cc.)
1	4	128	1, 024	61, 440	3, 785. 44
	1	32	256	15, 360	946. 36
		1	8	480	29. 57
			1	60	3. 70
				1	. 62

TEMPERATURE CONVERSION

Centigrade	Fahrenheit	Centigrade	Fahrenheit
−17. 80°	0°	32. 20°	90°
−15. 00°	5°	37. 80°	100°
−12. 20°	10°	42. 20°	110°
−9. 45°	15°	48. 90°	120°
−6. 67°	20°	54. 60°	130°
−3. 89°	25°	60. 00°	140°
0° freezing point	32° of water	65. 60°	150°
4. 45°	40°	71. 10°	160°
7. 22°	45°	76. 60°	170°
10. 00°	50°	82. 00°	180°
12. 80°	55°	87. 80°	190°
15. 60°	60°	93. 30°	200°
18° developing	65° temps.	98. 90°	210°
21. 10°	70°	100° boiling point of water	212°
23. 90°	75°	104. 40°	220°
26. 70°	80°	110. 00°	230°

To change Fahrenheit to centigrade: Subtract 32, multiply by 5, divide by 9.
To change Centigrade to Fahrenheit: Multiply by 9, divide by 5, add 32.

SAFELIGHTS

Eastman (wratten)	AGFA	Sensitized materials
Series 00	105	All chloride papers.
0	104	All bromide papers and lantern slide plates.
0A	104	All bromide and bromo-chloride papers, lantern slides, and process film.
1	104	For ordinary, medium, and extra-fast noncolor sensitive films.
2	107	All orthochromatic emulsions.
3	108	All panchromatic emulsions.
6A		X-ray films (not safe for orthochromatic materials).
	103	Ordinary panchromatic emulsions.
7	——	Infrared emulsion (not safe for orthochromatic or panchromatic materials).

FILTER FACTORS

Filter	Orthochromatic		Panchromatic		Ortho-panchromatic		Hyper-panchromatic	
	Day.	Tung.	Day.	Tung.	Day.	Tung.	Day.	Tung.
Aero 1	2	1. 5	2	---	1. 5	---	1. 5	---
Aero 2	2. 5	2	2. 5	---	2	---	2	---
K 1	2	1. 5	2	1. 5	1. 5	1. 5	1. 5	1. 5
K 2	2. 5	2	2. 5	2	2	1. 5	2	1. 5
K 3	2. 5	2	2. 5	2	2	1. 5	2	1. 5
NO 12	3	2. 5	3	2. 5	2	1. 5	2	1. 5
G	5	3	4. 5	3	3	2	2. 5	2
F	---	---	12	5	15	8	8	4
A	---	---	8	4	7	4	4	2
B	8	4. 5	12	9	6	6	7	6
C 4	9	12	10	15	12	24	12	24
C 5	3	3. 5	3	5	5	10	5	10
X 1	---	---	---	---	---	3	5	---
X 2	---	---	---	---	---	---	---	5

FILM SPEED RATINGS

Weston	General Electric	H and D	Scheiner
0.2	0.3	9	2
.5	.8	23	6
1	1.5	45	9
2	3	91	12
3	5	150	14
4	6	190	15
5	8	240	16
6	10	308	17
8	12	390	18
12	20	636	20
16	24	800	21
24	40	1,300	23
32	50	1,700	24
40	64	2,100	25
50	80	2,700	26
64	100	3,500	27
100	160	5,600	29
128	200	7,200	30
160	250	9,000	31
200	300	11,500	32
240	360	12,800	33
300	450	16,800	34

Density	Transmission (Percent)
0. 10	79. 4000
. 15	70. 8000
. 20	63. 1000
. 302	50. 0000
. 450	35. 5000
. 600	25. 0000
. 750	17. 8000
. 900	12. 6000
1. 000	10. 0000
1. 300	5. 0000
1. 600	2. 5000
1. 900	1. 2600
2. 000	1. 0000
2. 300	. 5000
2. 600	. 2500
2. 900	. 1256
3. 000	. 1000

Density = Log. $O = \text{Log.} \frac{1}{T}$

Appendix IV

GLOSSARY OF TERMS

Aberrations.—Errors in the performance of a lens which cause defects in photographs by distortion of light rays passing through the lens.

Abrasions.—Streaks occurring on emulsion surfaces which appear like pencil marks or scratches.

Accelerator.—Any substance which increases the activity of a developing agent and shortens developing time or the time in which an image appears.

Achromatic lens.—A lens which is partially corrected for chromatic aberration and brings red and green light rays to approximately the same plane of focus. Achromatic correction is obtained by cementing a positive lens of crown glass with a negative lens of flint glass.

Actinic.—Light which is capable of causing photo-chemical change in a sensitive emulsion. Actinic value varies with the sensitivity of the material. Blue and violet are the most actinic of the visible light rays.

Additive process.—Pertains to color photography. A process by which various visible colors are obtained by mixing or adding primary colors. Yellow for example is a mixture of red and green light rays in the proper proportion.

Affinity.—The readiness with which substances react with one another. Generally pertains to chemical reaction, and in photography, sodium sulfite has an affinity for oxygen thereby preventing oxidation of the developing agent in a developer.

Agitation.—The process of stirring or circulating a photographic solution to bring fresh solution in contact with the material which is being treated. This may be done by moving the material in the solution as in tank development, or by moving the solution itself as in tray development.

Air bells.—Small bubbles or spherical masses of air which attach to the surface of an emulsion and leave a small area unaffected by the solution. Can be removed by vigorous agitation of the solution.

Anastigmat.—A lens which has been corrected for astigmatism and thereby focuses vertical and horizontal lines with equal brightness and definition. Anastigmatic lenses are also free from other common aberrations.

Anhydrous.—Refers to chemical salts which contain no water of crystallization. Identical in meaning with "desiccated" which refers to dry chemicals.

Antihalation backing.—A coating, usually gelatin, on the back of a film containing a dye or colored pigment for the purpose of absorbing light rays, thus preventing their reflection from the back surface of the film base.

Aperture.—A small opening, usually circular, in a plate or sheet. In cameras, the aperture is usually variable in the form of an iris diaphragm and regulates the amount of light which passes through the lens.

Apochromatic.—Refers to lenses which are completely corrected for chromatic aberration. Focuses rays of all colors to very nearly the same plane.

Back focus.—The distance from the back or rear surface of a lens to the focal plane when the lens is focused at infinity. It is used in determining the length of camera bellows suitable for a given lens.

Blisters.—Small bubbles formed under an emulsion due to the detachment of the emulsion from its base.

Blow-up.—Photographic slang for enlarging.

Brightness range.—Variation in intensity from maximum to minimum. Generally refers to a subject to be photographed. For example, a particular subject may have a range of one to four, that is, the brightest highlight of the subject has four times the amount of light reflected from it as the least bright portion of the subject.

Brilliance.—A term denoting the degree of intensity of a color.

Cable release.—A flexible shaft for operating a camera shutter at a distance. Used to avoid camera movement when operating the shutter release lever with the hand.

Camera.—A device used for taking photographs consisting of a lightproof chamber, a lens, a means for focusing, a shutter and diaphragm to regulate exposure, and a means for holding a sensitized film or plate.

Cellulose acetate.—Main constituent of safety base film. Burns very slowly and is preferable to nitrate base.

Cellulose nitrate.—Base material for nitrate film base. Highly inflammable.

Chemical fog.—Fog produced in a sensitive emulsion by any chemical means. Often caused by very energetic or contaminated developer.

Cinematography.—The process of making motion pictures.

Circle of confusion.—The size of the image of a point formed by a lens. Should not be larger than $\frac{1}{100}$-inch in diameter. If a negative is to be enlarged, this circle should be considerably smaller than $\frac{1}{100}$ inch. This diameter is the maximum to produce a sharp image with the lens.

Color.—The property of an object which depends on the wave length of light it reflects. The sensation produced in the eye by a particular wave length or group of wave lengths of visible light.

Color sensitivity.—The sensitivity of a photographic emulsion to light of various wave lengths.

Composition.—A term referring to the grouping of objects in a photograph to obtain proper balance and accentuation of the main subject.

Condenser.—A lens used to collect rays of light from a source and project them in proper alinement to obtain even and undistorted illumination of a negative or positive. Used in condenser type enlarger and projection lanterns.

Contact print.—A print made by placing a sensitized emulsion in direct contact with a negative and passing light through the negative.

Contrast.—The difference between light intensities in a subject area such as between highlights and shadows. In a negative, the difference is between density values and in a print it is the reflective power between highlight and shadow.

Convertible lens.—A lens containing two or more elements which can be used individually or in combination.

Covering power.—The capacity of a lens to give a sharply-defined image to the edges of sensitized material it is designed to cover and at the largest possible aperture.

Darkroom.—A room for photographic operations, mainly processing, which can be made free from white light and is usually equipped with safelights emitting nonactinic light.

Definition.—The degree of sharpness of a photographic image dependent upon perfection or accuracy of the lens used to obtain the image.

Deliquescent.—The property of a chemical salt of absorbing moisture directly from the atmosphere.

Densitometer.—A device for measuring the density of a silver deposit in a photographic image. It is usually limited to measuring even density in very small areas. *Density* is the expression for denoting amount of light absorbed by a medium in relation to the light incident on it.

Desensitizer.—An agent for decreasing the color sensitivity of a photographic emulsion to facilitate development under comparatively bright light. The action is applied after exposure.

Developer.—A solution used to make visible the latent image in an exposed emulsion.

Diffusion.—The scattering of light rays upon reflection from a rough surface, or the transmission of light through a translucent medium.

Dispersion.—The separation of individual colors of light by differential refraction.

Distortion.—Defects in a photographic image by abnormal rendition perspective.

Dodging.—The process of holding back light from certain areas of the sensitized paper in making a print to avoid overprinting those areas. In projection printing, it is accomplished by inserting an opaque medium of proper shape and size between the lens and the easel and in contact printing, by either varying the illumination in given areas of the negative or inserting translucent or opaque paper between the light source and the negative.

Dry mounting.—A method for cementing a print to a mount by means of a thin tissue of thermoplastic material. The tissue is placed between the print and the mount and sufficient heat applied to melt the tissue. The tissue is usually impregnated with shellac which melts in the presence of sufficient heat.

Dyes, sensitizing.—Dyes used to extend the color sensitivity of silver halide. Applied in the manufacture of emulsions to obtain selective sensitivity to colored light.

Easel.—A device to hold sensitized paper in place before an enlarger. Generally includes an adjustable mask to accommodate different sizes of paper.

Effective aperture.—The maximum diameter of a lens as used for projection of images. This diameter is used in computing *f/* numbers.

Efflorescence.—The process by which a chemical salt loses its water of crystallization upon exposure to air.

Embossing.—The process by which the central portion of a print or mount is depressed, leaving a raised margin.

Emulsion.—The sensitive coating on films, plates, and papers composed of silver halide crystals suspended in gelatin.

Enlargement (*projection print*).—A photographic print made by projecting a negative to obtain an enlarged image on sensitized paper.

Exhaustion.—The state reached when the principal ingredient of any photographic solution is no longer active.

Exposure.—The length of time during which a given intensity of light is allowed to act upon a sensitive emulsion. Technically, it is the product of the time and the light intensity.

Exposure meter.—An instrument for measuring light intensity and determining correct exposure. It is calibrated for different emulsion speeds.

Fast lens.—A lens of relatively large aperture $f/4.5$, $f/3.5$, and $f/2$ are considered fast apertures for lenses.

Feather edge.—The edge of a print which has been treated with sandpaper or emery paper, and tapers from a very thin edge to the full thickness of the print. Its application is in assembling aerial mosaic prints to obtain a smooth joint between prints.

Ferrotype plates.—Sheets of thin enameled or chromium-plated iron used in obtaining high gloss of print. Some plates are made of polished stainless steel.

Fixing.—The process of removing the unexposed and undeveloped silver halide from a negative or print.

Flat.—Expression denoting lack of contrast in a print or negative.

Flatness of field.—The quality of a lens which affords sharpness of image both in the center and at the edges of the negative.

Focus.—The point toward which the rays of light converge to form an image after passing through a lens.

Focusing scale.—A graduated scale for different distances which permits focusing without the aid of a focusing screen.

Focusing screen.—A sheet of ground glass on which the image is focused and composed before exposure.

Forcing.—Attempting to bring out detail in an underexposed film, plate, or print by prolonged development or by the addition of an accelerator. Likely to produce fog.

Frilling.—The puckering up and detachment of the emulsion from the support around the edges; happens most often in hot weather or because of too much alkali in the developer.

Gamma.—A numerical measure of contrast in the development of a negative.

Gradation.—The range of tones from the brightest highlights to the deepest shadows.

Graininess.—The effect produced when the silver grains of a developed negative or print become visible. The relative sizes of grains determine the degree of graininess.

Halation.—A blurred effect, resembling a halo, usually occurring around bright objects; caused by reflection of rays of light from the back of negative material.

Halftones.—All gradations between highlights and shadows.

Halogen.—Iodine, bromine, chlorine, and fluorine are known as the halogens. Salts of these elements are called "halides."

Hard.—Used to denote excessive contrast.

Highlights.—Those portions of a subject upon which the greatest amounts of light fall. The densest parts of a negative and the lightest parts of prints.

Hydrometer.—An instrument used in photographic chemical mixing to find the concentration of a single chemical in water. Most common use is in mixing large quantities of hypo.

Hyper-panchromatic.—Term used to designate films and plates which have a high red sensitivity.

Hypo.—Abbreviation for the compound sodium thiosulphate, the most common fixing agent.

Imbibition.—Used in color photography. Process of dye transfer in the wash-off relief process.

Infinity.—Any great distance from a camera lens beyond which light rays from any point to the lens are regarded as parallel.

Infrared.—Invisible rays of light below the visible red. They extend from 700 to 13,000 millimicrons in wavelength.

Intensification.—The process of building up the density of a photographic image by chemical means.

Intensity (light).—The quantity of light emitted or reflected from a given source.

Irradiation.—The spreading of an image due to internal reflections within an emulsion. Causes a lowering of definition of the image.

Keeper.—An acid chemical added to developers to keep them in usable condition without oxidation of the developing agent with lapse of time.

Laboratory.—*a.* The plant or accomodation which permits photographic personnel and equipment to function.

b. The equipment and personnel allotted a photographic plant or accommodation.

Latent image.—The invisible image recorded by light action upon the film or plate and which is made visible in development.

Latitude.—*a. Exposure.*—The quality of a film or plate which allows variation in exposure without detriment to image quality.

b. Development.—Allowable variation in the recommended developing time without noticeable difference in contrast.

Light fog.—A graying of the image, produced by an unsafe darkroom lamp or accidental exposure to white light.

Matrix.—A positive print used in the wash-off relief process to hold the dye used in making the final print by imbibition.

Meter-candle-second.—Unit of exposure in sensitometry. The product of illumination or intensity in meter-candles and the exposure time in seconds.

Milky.—Appearance of an incorrect fixing bath; often the result of impure chemicals or improper mixing.

Mottled.—Irregular spots on negatives or prints.

Negative.—A photographic image on film, plate, or paper in which the dark portions of the subject appear light and the light portions appear dark.

Opaque.—Refers to an object which is incapable of transmitting visible light.

Orthochromatic.—Refers to films or plates whose sensitivity is to violet, blue, yellow, and green and which are insensitive to red.

Orthochromatic rendition.—In ordinary photography, this refers to the reproduction of color brightnesses in their relative shades of gray. In color photography, it is the reproduction of color as color.

Orthonon.—Name given to color-blind or noncolor sensitive emulsions.

Ortho-panchromatic.—Panchromatic emulsions which most nearly approximate the sensitivity of the eye.

Panchromatic.—Emulsions which are sensitive to all visible colors.

Photomontage.—A composite picture made by a number of exposures on the same film, by projection of a number of negatives to make a composite, or by cutting and pasting up a number of prints and subsequently copying to a new negative, or any similar method of making a composite print.

Photosensitive.—A term used to describe substances whose chemical composition is altered by the action of light.

Photostat.—A camera used to produce copies of documents, drawings, or photographs. The term also applies to the copy made with this type of camera.

Pinholes.—Minute transparent spots in negatives which show up as black spots in prints, most frequently caused by dust on the film.

Plane-parallel.—A term used to describe filter glasses whose faces are ground to flat, parallel surfaces.

Portrait.—A photograph of an individual; usually refers only to a head or head and shoulders.

Production.—The section or sections of a photographic laboratory which engage in or assist photographic processes. The product or products of photographic laboratory operation.

Proportional reducer.—A reducing solution which reduces the shadows at the same rate as the highlights and therefore produces no change in contrast.

Radiant energy.—A form of energy of electromagnetic character. All light which causes photo-chemical reduction is radiant energy.

Reducing agent.—Refers to development. The active ingredient of a developer which changes the subhalide to metallic silver. Usually requires acceleration.

Reflection.—The diversion of light from any surface.

Refraction.—The bending of light rays when passing from one medium to a medium of different density.

Refractive index.—The ratio of the speed of light in one medium to the speed in a medium of different density, or the ratio of the density of a medium to the density of air. Air is usually considered the standard medium in computing refractive index.

Relative speed of emulsions.—The rate at which one emulsion will record an image as compared with a standard emulsion of known sensitivity. Relative speeds are used in most speed rating systems.

Resolving power.—The measure of the ability of an emulsion to record fine detail. Fine-grain emulsions have high resolving power.

Restitution.—Projection printing for the purpose of minimizing variation in scale of prints from the true average scale.

Restrainer.—The chemical in a developing solution which holds back or checks the action of the developing agent.

Retouching.—The removal or softening of defects in a negative by means of pencil lines or color.

Scale.—Scale is the ratio of distance in the subject to the corresponding distance in the photograph.

Screen process.—A process incorporating minute colored particles, with the film or plate separate from the emulsion. The negative is exposed and reversed chemically to yield a positive. The grains which correspond in color to the original show through the emulsion and the remaining grains which do not correspond to the original are obscured by the overlying silver image.

Secondary color.—A color formed from the combination of two primary colors. Yellow, magenta, and cyan (blue-green) are the secondary colors.

Sensitometry.—The measurement of the response of a photo-sensitive material to the action of light.

Speed of an emulsion.—The rate at which an emulsion will record an image after it has been acted upon by light.

Speed rating.—An arbitrary number assigned to a photographic emulsion to designate its sensitivity in comparison with other emulsions. The individual numbers within a separate rating system are comparable with each other but not with the numbers of another system.

Spotting.—Retouching on prints with spotting colors or pencils.

Squeegee.—A strip of soft rubber mounted in a wooden frame or roller used for squeezing moisture from prints.

Stock solution.—Photographic solution in concentrated form which is diluted for use.

Subhalide.—Halides, generally referring to silver, which have been reduced from the halide form by the action of light.

Subtractive process.—Refers to color photography, a process in which two or more negatives are made through filters which subtract all but the desired color for each negative, and also in color printing processes in which the color desired is obtained by subtraction in a pigment or silver toning process.

Subtractive reducer.—A reducer which affects the shadows in a negative without noticeably affecting the highlights and thereby increases the contrast in the negative.

Superproportional reducer.—A reducing solution which lowers highlight density faster than it affects shadow density. The result is a lowering of the contrast of a negative.

Synchro-flash.—A term applied to photography in which a flash bulb is ignited at the same instant that the shutter is opened.

Synchronizer.—A device for operating a shutter simultaneously with the firing of a flash bulb.

Time gamma curve.—A curve of developing time plotted against develop-contrast or gamma. The contrast for any given time may be read directly from the curve, or vice versa. The curve applies for only one developer and one particular emulsion.

Tone.—Each distinguishable color or shade from black to white.

Toning.—The chemical treatment of a photographic image to obtain a colored image from a black and white one.

Translucent.—Semitransparent. A substance which passes light but diffuses it so that objects cannot be clearly distinguished.

Transparency.—A positive image on a clear base which must be viewed by transmitted light. Also refers to the light transmitting power of the silver deposit in a negative and is the inverse of opacity.

Vignette.—Ordinarily refers to projection printing. A process of regulating the distribution of light which reaches the print in such a way that the image obtained fades out toward the edges.

Weak image.—The image on a print or negative which is lacking in contrast and density.

Working aperture.—The largest diaphragm opening at which a lens will give satisfactory definition over the area of a film or plate which is covered by an image.

Working solution.—A photographic solution which has been diluted from a stock solution and is ready for use.

INDEX

INDEX

INDEX

INDEX

INDEX

[A. G. 062.11 (1–3–41).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

E. S. ADAMS,
Major General,
The Adjutant General.

DISTRIBUTION:

B (2); R and H 1 (6); R 2, 4, 6, 7, 10, 17 (2), 5 (5); Bn 1, 5, 11 (2); IBn 1 (10); C 11 (2).

(For explanation of symbols, see FM 21–6.)

U. S. GOVERNMENT PRINTING OFFICE: 1941

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 35 cents